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PLACER-MINING METHODS AND COSTS IN ALASKA

BY

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INTRODUCTION

Active placer mining in Alaska began near Juneau in 1880, but the first gold rush did not start until 1896; then the discovery of the Klondike brought gold seekers from all parts of the world. A few of the newcomers were experienced miners, but the majority knew nothing whatever of placer mining. Even those who were placer miners of much experience found entirely new conditions, notably frozen ground, that presented many difficult problems. As a result, numerous methods of mining and of thawing frozen ground were tried. From these trials the practice described in this bulletin has been developed.

All known placer fields in Alaska have been mined to some extent, and some have been virtually exhausted. In most districts, however, there remain large quantities of low-grade gravel and also some small isolated areas of comparatively rich gravels which could not be successfully mined because of adverse physical conditions. These districts are now the scene of most placer mining, including dredging, hydraulicking, drifting, mechanical methods of open-cut mining, and ground sluicing (or booming) followed by "shoveling-in."

As the richer areas were exhausted, fewer mines were worked and production declined. The increased cost of supplies incident to the World War depressed mining further. Economic conditions are now much better, the cost of equipment and supplies is lower than for years, and transportation to the more important districts, especially those reached by the Alaska Railroad and its river steamers, has improved. Methods of thawing frozen gravel with water at natural temperature have been developed, and the efficiency of mechanical equipment and power generation has been advanced. Mining costs have been reduced thereby and an impetus given to placer mining.

REPORTS OF GEOLOGICAL SURVEY

The published reports of the United States Geological Survey, which cover more than 30 years' work in Alaska and include geological studies, water-supply papers, investigations of placer mining, and the annual reports on the Alaska mining industry, have been invaluable. Most of this work was directed by the late Dr. Alfred H. Brooks, who, as chief geologist of the Alaska division for 25 years, probably did more than any other person to aid mining in Alaska. In 1904, when Alaska placer mining was nearing its peak of production, the late C. W. Purington investigated methods and costs of gravel and placer mining; his excellent report thereon [1] has been accepted as authoritative for Alaska practice. Meanwhile, many other placer districts have been discovered and actively mined, mining practice has been modified and improved, and economic conditions have changed.

SCOPE OF BULLETIN

This bulletin gives the results of a study of present conditions in Alaska placer mining, including the methods employed and the costs, and will be helpful to placer miners, engineers, and all others interested in the industry.

Gold placers are widespread in Alaska. There are more than 50 known mining centers, the relative locations of which are indicated on the map (fig. 1). The writer could examine only the typical districts, beginning his field work at Nome in June, 1922, and later visiting the Solomon, Council, and Bluff districts on Seward Peninsula, then the Ruby, Hot Springs, Rampart, and Fairbanks districts. In 1923 he examined the Iditarod, Innoko, a part of the Kuskokwim, the Fairbanks, Yentna, Nizina, and Girdwood districts. In August, 1924, he made an airplane flight of 220 miles from Fairbanks to Eagle and visited part of the Fortymile district, the Eagle, Seventymile, and Circle districts, and later the Fairbanks and Girdwood districts. John A. Davis, of the Bureau of Mines staff, visited the Koyuk, Candle, Inmachuck, Nome, Solomon, and Council districts on the Seward Peninsula during 1924 to obtain further data for this bulletin. Although operators willingly supplied available data on operating practice and costs, only information that was deemed pertinent has been used. To check figures as to the area or yardage mined, the average amount of water used, and similar details has been practically impossible, but the figures given are the best obtainable. The investigator did not attempt to sample deposits, ascertain the extent of gold-placer reserves, determine the water resources, or study similar features in detail.

Valuable material on some districts which could not be visited was obtained by conferences or correspondence with operators and other responsible persons. Government publications and many

[1] Purington, C. W., Methods and Costs of Gravel and Placer Mining in Alaska: U. S. Geol. Survey Bull. 263, 1905, 273 pp.

articles on placer mining in Alaska that have appeared in the technical press have been liberally used.

The costs given are operating costs only, unless otherwise noted. In general, they do not include royalty, taxes, and charges for depreciation, interest, amortization, and depletion, which may or may not be considered by the operator. These are regarded as capital charges and may be nominal in some instances but are generally large and at some mines may exceed the operating cost. It is impractical to figure average costs for the different types of mining. Mining is conducted under too widely differing conditions, and an average cost based on costs of a number of mines would be very misleading; therefore, the range of cost for different kinds of placer mining, with some exceptions, is given and specific examples are more or less fully described.

As the work progressed, descriptions of placers, mining methods employed, and conditions at representative camps were published in the annual reports of the Territorial mine inspector for 1922, 1923, and 1924 to make the essential information available as quickly as possible. Because many requests for lists of articles and books on placer mining have been received, a selected bibliography is printed at the end of this bulletin.

ACKNOWLEDGMENTS

The hearty cooperation and help which mine operators, business men, transportation companies, and Government officials gave is most gratifying; their assistance made this work possible.

Special acknowledgment is given the late Dr. Alfred H. Brooks, of the United States Geological Survey; to B. D. Stewart, of the Bureau of Mines; and to Charles Janin, of San Francisco, Calif., consulting engineer of the Bureau of Mines.

HISTORY

DISCOVERY OF GOLD FIELDS

A Russian engineer in 1850 made the first reported discovery of placer gold in Alaska. That discovery was in the Kenai River Basin. A little mining was done there, but the placers were soon abandoned. During the early seventies gold was found in the Tanana Valley, but placer mining in Alaska did not really start until the discovery of gold near Juneau in 1880; prospecting then began in earnest. In 1886 gold was found in the Fortymile district (fig. 1, *41*), and in 1893 and 1894 in the Rampart district (fig. 1, *31*) and the Birch Creek placers of the Circle district (fig. 1, *37*). Although these districts were actively mined, the annual production was not large enough to arouse unusual interest. With the discovery of the Klondike, in 1896, excitement ran high. A few years later the rich deposits at Nome were discovered, followed by discoveries at Koyukuk, Hot Springs, and Fairbanks (fig. 1, *13*, *30*, and *33*). The last important discovery was the Tolovana (fig. 1, *32*) in 1915. The map (fig. 1) shows the chief gold-placer districts and mining centers. The localities designated do not by any means cover all known occurrences of placer gold, and in some of the districts mentioned little if any placer mining is now being done.

PRODUCTION

The following table shows the year the principal districts made the first production recorded, and the total value of the placer gold and its alloyed silver produced to 1922, inclusive.

Value of the placer gold and silver produced by districts to 1922, inclusive [a]

District	First year of production	Value of gold and silver produced to 1922	District	First year of production	Value of gold and silver produced to 1922
Fortymile	1886	$6, 506, 000	Ruby	1907	$5, 450, 000
Circle	1894	6, 775, 000	Innoko-Tolstoi	1907	3, 023, 000
Rampart	1896	1, 610, 000	Eagle and Seventymile	1908	349, 000
Seward Peninsula	1897	83, 650, 000	Iditarod	1910	19, 108, 000
Koyukuk	1900	4, 904, 000	Chisana	1913	648, 000
Hot Springs	1902	6, 300, 000	Marshall	1914	1, 136, 000
Fairbanks	1903	72, 340, 000	Tolovana	1915	4, 055, 000
Bonnifield	1903	286, 500	All others	1880	12, 955, 000
Kantishna	1903	512, 000			
Richardson	1905	1, 738, 000	Total		231, 620, 500
Chandalar	1906	255, 000			

[a] Compiled from statistics published by U. S. Geological Survey.

During 43 years of mining (1880 to 1922) Alaska produced gold valued at $335,526,460; of this amount $230,507,000 should be credited to placer mines. In addition, $1,113,500 worth of silver was recovered, most of which was alloyed with the gold.

Of this total more than $200,000,000 has been mined since 1900, when the industry received its first great stimulus by the gold output of the Nome district. Other bonanza deposits were soon discovered, and by 1906 the value of the anual output of placer gold had reached $18,600,000 and the industry employed 8,000 men. From 1906 the annual output declined, and by 1913 its value was reduced to $10,680,000 and the number of miners to 4,700. It should be noted that this reduction (45 per cent) in the value of the placer output took place before the war, and that it indicated the rapid exhaustion of the bonanza deposits. * * *

The output of gold dredging increased in value from $20,000 in 1903 to $2,200,000 in 1913. Dredges had been built so actively before the war that in spite of adverse conditions they continued to increase their output, which did not reach its maximum until 1916, when its value was $2,679,000. The hard times that followed led not only to the shutting down of the dredges already built but to the abandonment of some new projects. The dredges reached their minimum output of gold in 1920, when its value was $1,130,000. This rise and decline before 1920 was paralleled by similar though smaller fluctuation in hydraulic and other mechanical mining.[2]

The following tables, published by the United States Geological Survey,[3] show the recovery per cubic yard, the yardage of gravel mined, and the value of gold recovered annually. The increased yardage mined and the decrease in the average value of gold recovered per cubic yard during 1923 are noteworthy; they are due mainly to two large dredges at Nome which began work that year.

Gravel sluiced in Alaska placer mines and value of gold recovered, 1908 to 1923

Year	Total quantity of gravel, cubic yards	Value of gold recovered per cubic yard	Year	Total quantity of gravel, cubic yards	Value of gold recovered per cubic yard
1908	4, 275, 000	$3. 74	1916	7, 100, 000	$1. 57
1909	4, 418, 000	3. 66	1917	7, 000, 000	1. 40
1910	4, 036, 000	2. 97	1918	4, 931, 900	1. 20
1911	5, 790, 000	2. 17	1919	4, 548, 700	1. 10
1912	7, 050, 000	1. 70	1920	3, 439, 900	1. 13
1913	6, 800, 000	1. 57	1921	4, 812, 700	. 88
1914	8, 500, 000	1. 26	1922	5, 226, 000	. 84
1915	8, 100, 000	1. 29	1923	6, 015, 595	. 60

Relation of recovery of placer gold per cubic yard to proportion produced by dredges

Year	Percentage of placer gold produced by dredges	Recovery per cubic yard		
		Dredges	Mines	All placers
1911	12	$0. 60	$3. 36	$2. 17
1912	18	. 65	2. 68	1. 70
1913	21	. 54	3. 11	1. 57
1914	22	. 53	2. 07	1. 26
1915	22	. 51	2. 33	1. 29
1916	24	. 69	2. 64	1. 57
1917	26	. 68	2. 21	1. 40
1918	24	. 57	1. 84	1. 20
1919	27	. 77	1. 31	1. 10
1920	29	. 69	1. 53	1. 13
1921	37	. 57	1. 31	. 88
1922	40	. 55	1. 29	. 84
1923	51	. 40	1. 28	. 60

[2] Brooks, A. H., and Capps, S. R., "Alaskan mining industry in 1922"; Mineral Resources of Alaska, 1922: U. S. Geol. Survey Bull. 755, 1924, p. 10.
[3] Brooks, A. H., "Alaska's mineral resources and production, 1923"; Mineral Resources of Alaska, 1923: U. S. Geol. Survey Bull. 773, pp. 1–52.

Gold produced by dredge mining in Alaska, 1903 to 1923

Year	Number of dredges operated	Value of gold output	Gravel handled, cubic yards	Value of gold recovered per cubic yard
1903	2	$20,000		
1904	3	25,000		
1905	3	40,000		
1906	3	120,000		
1907	4	250,000		
1908	4	171,000		
1909	14	425,000		
1910	18	800,000		
1911	27	1,500,000	2,500,000	$0.60
1912	38	2,200,000	3,400,000	.65
1913	35	2,200,000	4,100,000	.54
1914	42	2,350,000	4,450,000	.53
1915	35	2,230,000	4,600,000	.51
1916	34	2,679,000	3,900,000	.69
1917	36	2,500,000	3,700,000	.68
1918	28	1,425,000	2,490,000	.57
1919	28	1,360,000	1,760,000	.77
1920	22	1,129,932	1,633,861	.69
1921	24	1,582,520	2,799,519	.57
1922	23	1,767,753	3,186,343	.55
1923	25	1,848,596	4,645,053	.40
		26,723,801		

Gold and silver produced from placer mines in Alaska in 1922, by regions

Region	Gold		Silver		Gravel mined	
	Fine ounces	Value	Fine ounces	Value	Cubic yards	Recovery per cubic yard
Southeastern Alaska	145.13	$3,000	23	$23	1,800	$1.67
Copper River region	7,981.88	165,000	851	851	305,747	.54
Cook Inlet and Susitna region	14,173.88	293,000	2,095	2,095	593,788	.49
Yukon Basin	102,506.61	2,119,000	13,751	13,751	1,999,167	1.01
Kuskokwim region	26,219.25	542,000	2,815	2,815	215,950	2.50
Seward Peninsula	61,194.37	1,265,000	6,790	6,790	2,103,691	.60
Kobuk region	387.00	8,000	44	44	5,857	1.37
	212,608.12	4,395,000	26,369	26,369	5,226,000	.84

Statistics of placer mining in Alaska, 1922 and 1923

Region	Number of mines				Number of miners				Value of gold produced		
	Summer		Winter		Summer		Winter		1922	1923	Decrease or increase, 1923
	1922	1923	1922	1923	1922	1923	1922	1923			
Southeastern Alaska	2	5	1		3	12	2		$3,000	$3,500	+$500
Copper River region	8	9	5	3	91	86	18	11	165,000	144,000	−21,000
Cook Inlet and Susitna region	36	35	1		174	180	2		293,000	247,000	−46,000
Yukon Basin	321	301	99	64	1,254	1,078	321	243	2,119,000	1,644,000	−475,000
Kuskokwim region	30	28		2	137	106		4	542,000	292,000	−250,000
Seward Peninsula	104	60	11	6	528	606	51	29	1,265,000	1,270,000	+5,000
Kobuk region	6	8	3		11	13	8		8,000	8,000	
	507	446	120	75	2,198	2,081	402	287	4,395,000	3,608,500	−786,500

FUTURE OF ALASKA PLACER MINING

VALUE OF RESERVES

The volume and gold content of gravel reserves in the known fields may be roughly estimated, although so many different conditions affect the cost of mining that it is almost impossible to gauge even approximately how much of this gold can be recovered with profit. Gravel of tenor workable in one locality may be worthless in another where conditions are less favorable, and gravels now considered valueless may in future be considered ore through improvements in mining practice. Brooks[4] estimates the value of the available placer-gold reserve in the developed districts of Alaska at $360,000,000 and perhaps twice that amount; there is, moreover, the possibility of new discoveries.

Some years ago the value of the gold reserves in the gravel-plain, ancient beach, and high-bench placers of Seward Peninsula was estimated at about $215,000,000 and that of the creek deposits at about $50,000,000.[5]

Prindle[6] valued the gold-placer reserves of the Fairbanks district, excluding some possible dredging areas, at about $50,000,000.

In 1919 a committee (Alaska chapter of the American Mining Congress) of experienced operators of mines at Fairbanks, under the direction of John A. Davis, of the Bureau of Mines, estimated that the creeks tributary to Fairbanks contained 219,200,000 cubic yards of dredging ground having an average gold content of about 45 cents per cubic yard, totaling $100,200,000.

The Klondike district in the eight years ended about 1905 produced $107,000,000 in gold; since then by hydraulic mining and dredging it has produced gold worth more than $70,000,000. Compared with development in the Klondike, placer mining in some Alaska districts is still in its infancy. Dredging recently started at Nome and investigations near Fairbanks would indicate the beginning of a somewhat similar era in those districts.

These estimates all show that far more gold still remains in the known placer fields than has been mined. Future production from these known fields probably will never reach these estimates, however, although results indicate that the Nome and Fairbanks districts may equal if not exceed their past yield.

[4] Brooks, A. H., "The future of Alaska mining"; Mineral Resources of Alaska, 1919: U. S. Geol. Survey Bull. 714, 1921, pp. 9–11.

[5] Collier, A. J., and others, The Gold Placers of Parts of Seward Peninsula, Alaska: U. S. Geol. Survey, Bull. 328, 1908, p. 138.

[6] Prindle, L. M., A Geologic Reconnaissance of the Fairbanks Quadrangle, Alaska: U. S. Geol. Survey Bull. 525, 1913, p. 115.

MINING METHODS

In the early days of placer mining in Alaska selective mining of the richer ground occasioned much waste. Many deposits were so gouged that reworking would be impracticable. Much of the mining was neither efficient nor thorough, the lower-grade gravel, or that which could not be mined profitably by the methods employed, was left behind, gold was lost in the tailing, or the bedrock was not properly cleaned. These placers are now the scene of most of the present activity, and many more still await investigation. Bench deposits occur in most of the districts, and although many have been mined to some extent the possibilities of most of them are still to be determined.

A large amount of prospecting and drilling was done during the earlier days, and it is thought that many placer deposits which were not considered worth mining then would be deemed satisfactory now. Records of former work have unfortunately been either lost or forgotten, and such areas must be reprospected. Moreover, although many creek beds are known to be gold bearing, they have never been prospected thoroughly enough to determine their possibilities. Development in certain districts has also been retarded by the excessive prices or royalties asked by some owners of prospects.

Prospecting in new fields is increasing, and although some new gold discoveries have been recently made, they have been unimportant. However, as a great area is still to be prospected, new discoveries of importance can be confidently anticipated, although it is possible that no discoveries as extensive and rich as some of those in the past will be made.

MINING BY HAND

Manual mining methods, such as ground sluicing and booming, followed by shoveling in, are suitable where small isolated areas are to be mined with a minimum outlay of capital. Such methods, rapidly passing in most of the districts, will always be popular with many miners who are content with small returns, or a bare livelihood. Drift mining is rapidly declining but is generally the only method practicable for mining deep channel deposits where the gravel is frozen and the main gold content is concentrated in a comparatively thin stratum, usually at bedrock.

MECHANICAL MINING

Shallow placers, otherwise suitable for dredging but too small to justify the installation of a dredge, afford opportunity for open-cut mining by other mechanical means. However, digging conditions must be favorable for the type of machine employed. The gravels must be shallow, or barren overburden, if there is any, must be cheaply removed, otherwise mining may be unprofitable. Most of the mechanical devices formerly used were too costly to operate and were not mobile enough. The steam scrapers, especially the bottomless type, have done satisfactory work, but their period of usefulness is passing; in many instances they have been succeeded by dredges. The drag-line excavator and the cableway excavator answer many of the requirements for economical and efficient operation, as they afford mobility and can deliver the gravel directly to the sluices, without intermediate handling.

HYDRAULIC MINING

Hydraulic mining will always be favored where conditions permit. There is an extensive field for it in Alaska, although in most districts it will be restricted to working comparatively small areas because deep, extensive deposits with the stream gradient and water supply necessary for large-scale, low-cost mining are rare. In Alaska the small inexpensively equipped mine that requires only a small crew is generally best suited for hydraulic mining.

DREDGING

The increasing search for dredging ground and the growing number of dredges, especially recent large-scale developments, reflect conditions in the Alaska placer-mining industry. Dredging now produces more than half of the Alaska placer gold. This proportion may be expected soon to increase as other methods of mining give way to the more efficient and less costly mining by dredges.

CONDITIONS AFFECTING PLACER MINING

Short operating seasons, frozen ground, isolated districts with difficult transportation conditions, high freight rates, and high-priced labor militate against low operating costs; nevertheless there is still a vast field of opportunity for experienced and efficient operators. Under certain favored conditions placer mining in Alaska has been and can be conducted at operating costs which compare favorably with those attained elsewhere. In general, Alaska placers can never be worked as cheaply as those in other countries where conditions are more favorable, so it may be said that although much low-grade gravel remains a great deal of it will never be mined at a profit.

The necessity for carefully prospecting the ground and thoroughly investigating all conditions that affect mining, in order that the right method of mining can be selected, can not be emphasized too strongly; unless care and judgment are exercised failure may be expected. In the past not only have placer properties been taken over after too meager investigation, but in disregard of ordinary business principles an otherwise suitable property has been handicapped with an astounding amount of overhead or capital invested in equipment.

The conditions that affect placer mining, the methods of mining that have been developed through experience to meet Alaska conditions, and the cost of conducting such operations under widely different conditions are discussed in the following pages.

NATURAL CONDITIONS

GEOGRAPHY [7]

Alaska and the Aleutian Islands lie between the meridians of 130° west longitude and 173° east longitude and between the parallels of 51 and 72° north latitude, or in approximately the same latitude as the Scandinavian Peninsula. The western end of the Aleutian Islands has almost the same longitude as the New Hebrides Islands and New Zealand; and Cape Prince of Wales, the most westerly point of the mainland, is nearly as far west as the Samoan Islands.

The Territory has an area of 590,880 square miles, more than twelve times that of New York State, or practically one-fifth that of the United States proper. Its southern point is 700 miles from the State of Washington by the route usually traveled. The southeastern archipelago and strip of mainland extend northwest about 520 miles to the major part of the Territory, which measures approximately 900 miles from north to south and 700 miles from east to west; from the southwestern part the Alaska Peninsula and Aleutian Islands reach out nearly 2,500 miles toward Siberia.

A map of Alaska superimposed on a map of the United States of the same scale reaches from the Atlantic to the Pacific in the latitude of Los Angeles, and its most northern and most southern points are nearly as far apart as Mexico and Canada.

TOPOGRAPHY

The topography of Alaska is so complex that to present briefly even the salient features is not easy. Because of the importance of topography as a factor in placer mining, the reader is referred to the many topographic maps published by the United States Geological Survey.

[7] Compiled mainly from data by Brooks, A. H., The Geography and Geology of Alaska, a summary of existing knowledge: U. S. Geol. Survey Prof. Paper 45, 1906, pp. 14–17.

GEOLOGICAL FEATURES

The formation of gold placers is determined by (1) the occurrence of gold in bedrock to which erosion has access, (2) the separation of the gold from the bedrock by weathering or erosion, and (3) the transportation, sorting, and deposition of the auriferous material derived from erosion.

CLASSIFICATION OF PLACERS

Alaska placers may be classified according to origin as residual, sorted, and re-sorted.[8] Residual placers are formed practically in place with little or no transportation of the gold by water. Sorted deposits are the result of transportation, sorting, and deposition by water. Re-sorted placers are those in which the auriferous material has passed through two or more periods of erosion before its final deposition.

Brooks gives a classification,[9] based on form, as follows:

Creek placers.—Gravel deposits in the beds and intermediate flood plains of small streams.

Bench placers.—Gravel deposits in ancient stream channels and flood plains which stand from 50 to several hundred feet above the present streams.

Hillside placers.—A group of gravel deposits intermediate between the creek and bench placers. Their bedrock is slightly above the creek bed, and the surface topography shows no indication of benching.

River-bar placers.—Placers on gravel flats in or adjacent to the beds of large streams.

Gravel-plain placers.—Placers found in the gravels of the coastal or other lowland plains.

Sea-beach placers.—Placers reconcentrated from the coastal-plain gravels by the waves along the seashore.

Ancient beach placers.—Deposits found on the coastal plain along a line of elevated beaches.

Lake-bed placers.—Placers accumulated in the beds of present or ancient lakes that were generally formed by landslides or glacial damming.

It is evident that these classifications contain intermediate types which may belong to either of the two groups. Most of the placer gold that has been mined in Alaska comes from creek, bench, and beach deposits.

CREEK PLACERS

Residual placers have been found at a number of localities, notably at the head of Flat, Happy, and Chicken Creeks in the Iditarod district (fig. 1, *21*), but have not been an important source of gold. Creek and bench deposits are found in virtually all the districts.

[8] Brooks, A. H., "The mineral deposits of Alaska"; Mineral Resources of Alaska, 1913; U. S. Geol. Survey Bull. 592, 1914, pp. 25–32.

[9] Brooks, A. H., Outline of economic geology; The Gold Placers of Parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, 1908, pp. 114–145. Lake-bed placers not included.

They may be of either ancient or modern origin, or of the sorted or re-sorted types. Modern creek placers occupy the present creek channels and usually contain gravels from a few feet to 10 feet or more deep. The sorted ancient placers are those in the benches or terraces along present streams and have all the characteristics of the modern creek placers except that they have been dissected. Such bench placers are quite common in many districts. The deeply buried channels or "deep gravels" are deposits of ancient water-courses which occupied the present valleys, but are now buried under a thick covering of alluvium. These deep channels usually have a rather straight course with only a few large bends, lie on a bedrock floor whose downstream slope is generally a little steeper than that of the present valley bottoms, and ordinarily are centrally situated with reference to the bedrock slope of the valley. In the headwater regions of the creeks the deep gravels may merge with those of the present streams, and here the entire section may consist of gravels. The best examples of these deposits are in the interior of Alaska, particularly in the Fairbanks, Hot Springs, Tolovana, and other districts in the Yukon-Tanana region (fig. 1, *30*, *32*, and *33*). Here the gravels, which ordinarily are 10 to 40 feet thick, are buried under an accumulation of muck or black humus, fine gray sand, silt, and clay, 10 to 300 feet and more thick.

BENCH PLACERS

Bench placers have all the characteristics of modern stream placers, but their bedrock floor is higher than the present bed of the stream. Gravel terraces are wide flat gravel deposits, whose surfaces are considerably above the high-water level of the stream and whose bedrock floors are only slightly, if at all, higher than the stream bed. The present streams have cut into the thick covering of the deep channel deposits, forming surface terraces that resemble benches, although the bedrock floor generally has the same elevation as that of the present stream bed; such deposits are often wrongly classed by many miners as bench deposits. High-bench deposits have resulted from the action of streams of a former drainage system, now preserved only in fragmentary form. Unlike the bench deposits of the present valleys, they have no direct relation to existing drainage channels. These high gravels are sometimes called "bar" deposits. The best examples are in the Rampart, Hot Springs, and Ruby districts (fig. 1, *28*, *30*, and *31*), where they are low grade and have not been workable to any extent. Some of the high-bench placers near Nome, which form the divide between Dexter and Anvil Creeks, have, however, been quite productive.

SEA-BEACH PLACERS

Sea-beach deposits of the modern type are virtually all re-sorted; they have been formed by wave action which erodes adjacent alluvial deposits and concentrates their gold contents in places along the beach. Such deposits occur along the Pacific seaboard at Lituya Bay, at Yakataga, Kodiak Island, and elsewhere. The most important beach placers are at and near Nome; large amounts of gold have been won from them. Sea-beach placers are usually of small extent, but each high surf causes new enrichments.

The ancient re-sorted sea-beach placers probably include the same types as the modern ones. At Nome there are both submerged and elevated beach placers, formed at times when the land stood at different altitudes with respect to the sea. These beach lines have been very productive. The gravels are covered with muck and overburden, and, in general, their total depth ranges from 30 to 100 feet.

RIVER-BAR, GRAVEL-PLAIN, AND OTHER PLACERS

River-bar placers contain mostly fine gold, deposited at certain places of minimum water movement. Some of these placers have been profitably mined by hand labor; most of them are not extensive enough to repay work on a larger scale, as by dredging. Hillside placers do not occupy well-defined channels but are a transitional type between residual and gulch placers. River-bar and hillside placers are unimportant commercially.

Gravel-plain placers are in part modern but are chiefly ancient; they are somewhat intermediate between creek and river placers. Of this type are the so-called "tundra" placers of Nome, whose present importance has been due chiefly to their having supplied gold to some of the re-sorted beach and stream placers. Glacial deposits may contain gold but have little economic value unless they have been re-sorted by post-glacial streams or have derived their gold from an unusually rich primary source.

In most Alaska placers the gold is found chiefly on or near bedrock but may be present in economic quantities 10 to 20 feet and even more above, although the upper gravel is rarely rich enough to be mined alone. Some placers have two or more pay strata separated by beds of muck, sand, clay, or low-grade or barren gravel. Gold is also found in the bedding planes and crevices of bedrock, generally not more than a foot or two below its top, although in seamy ground, particularly limestone and schist, it may continue 10 feet or more in the bedrock. In many placers the bedrock has formed a sticky clay or "gumbo," and the gold may lie on or be distributed through this clay. The coarsest gold is generally found in the lower gravel or on bedrock, and at the creek and bench deposits, especially the rich channel placers, it lies in well-defined pay streaks. As the outer limits of a deposit are reached and the tenor of the gravels diminishes, the gold becomes finer. Gold in the marginal gravels is known as "side pay." However, there are numerous re-sorted placers, especially in the interior, without definite pay streaks or channels; in these the gold is often coarse and lies in irregular patches.

The placers in the narrower valleys often range from about 50 to as much as 500 feet wide and usually are V-shaped. In the wider and flatter valleys dredging over maximum widths up to 1,000 feet has often been practical; at several places the pay gravel has been found to be more than 2,000 feet wide. The general character and the depths of the placers being mined are described in more detail under "Mining methods."

MINERALS ASSOCIATED WITH PLACER GOLD

Accessory minerals associated with placer gold are magnetite, pyrite, garnet, ilmenite, tourmaline, ruby, and others of rarer occurrence. In the Nizina district (fig. 1, *47*) much native copper and some silver are recovered in the sluices. Native silver has been found in a number of other districts. Alluvial tin or cassiterite is found with the gold in the Ruby (fig. 1, *28*), Circle (fig. 1, *37*), and other districts and is a valuable by-product in the Hot Springs (fig. 1, *30*) district. Alluvial tin was at one time a by-product of placer mining for gold in the York region on the Seward Peninsula, and some of those placers were later mined chiefly for their tin content. Cinnabar, scheelite, wolframite, barite, and galena are frequently found in the gold placers of many districts. Platinum has been found along a number of creeks in the Yukon Basin and southwestern Alaska and is recovered in commercial quantities with the gold at Dime Creek (fig. 1, *5*) on the Seward Peninsula.

CLIMATE

Alaska's geographic position, extent, and varied topographic features have produced physical conditions that make strong contrasts between the different districts. Nearly three-quarters of Alaska lies within the North Temperate Zone, and the climate is by no means as uniformly arctic as people unfamiliar with conditions believe it to be.

Although some of the districts farther north have very cold, rigorous winters, in general the climate is healthful and invigorating. The open season, although somewhat variable, averages from May to October. The length of the season for placer mining is three to six months, varying with the locality and the method of mining employed. One noteworthy effect of Alaska climate is the frozen condition of the ground, which prevails in most of the districts.

There are three general climatic regions in Alaska, and each in turn includes a number of subordinate provinces.[10]

The maritime region adjacent to the Pacific Ocean has a heavy annual precipitation (50 to 190 inches), a comparatively high mean annual temperature (35 to 48° F.), cool summers (mean temperatures 50 to 55° F.), and mild winters (mean temperatures 20 to 35° F.). Maximum annual variations are comparatively small compared with those of the western provinces, the records showing from —27 to 94°. The inland region beyond the coastal mountains has a continental semiarid climate (precipitation 9 to 15 inches), comparatively warm summers (mean temperatures 50 to 58° F.), and cold winters (mean temperatures 0 to —15° F.). The range of extreme temperature is striking, from —76 to 100° F., but the range of mean annual temperature is 15 to 27° F. The region tributary to the Arctic Ocean has a precipitation of only about 6 to 8 inches, an average summer temperature of 40 to 45° F., a winter temperature of about —10 to 16° F., and an extreme variation of —54 to 66° F.

The climate of the coastal region is comparable with that of Scotland and the Scandinavian Peninsula in Europe, but is somewhat warmer; the climate of the inland region is not unlike that of Alberta, Saskatchewan, and Manitoba in Canada. The northerly region bordering the Polar Sea is the only one in which arctic conditions prevail. The season of 1922 in most of the placer districts was cold and rainy, thawing was slow, but there was an unusually large supply of water, whereas the season of 1923 was dry and hot, with a drought that lasted several months. These years showed such decided changes from the normal that they can be taken as examples of maximum and minimum conditions. The accompanying climatological tables for these two years were compiled from annual reports of the United States Weather Bureau at Juneau.[11]

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[10] Report of the Alaska Railroad Commission: House Doc. 1346, 62d Cong., 3d sess., pp. 28–32. The figures have been revised by the U. S. Weather Bureau, Department of Agriculture.

[11] Summers, M. B., Climatological Data, Alaska section, 1922: Department of Agriculture, U. S. Weather Bureau, Juneau office. Mize, R. C., Climatological Data, Alaska section, 1923: Department of Agriculture, U. S. Weather Bureau, Juneau office.

Alaska climatological data for 1922 and 1923

Station	Length of record, years	Temperature: Annual mean, ° F.	Temperature: Departure from normal, ° F.	Temperature: Highest, ° F.	Temperature: Date	Temperature: Lowest, ° F.	Temperature: Date	Precipitation: Total for year, inches	Precipitation: Percentage of normal	Precipitation: Greatest monthly, inches	Precipitation: Monthly	Precipitation: Least monthly, inches	Precipitation: Month	Precipitation: Total snowfall, inches	Sky: Number of rainy days	Sky: Number of clear days	Sky: Number of partly cloudy days	Sky: Number of cloudy days	Freezing temperature: Last date in spring	Freezing temperature: First date in autumn	Freezing temperature: Number days between last freezing temperature in spring and first in autumn	Rivers and harbors: Date ice broke in spring	Rivers and harbors: Date closed in autumn
Juneau	28	41.2	−0.9	79	May 29	0	Feb. 8	81.91	103	11.56	January	2.16	December	60.5	222	73	35	257	May 7	Oct. 3	149	(a)	(a)
	29	43.7	+1.7	87	Aug. 20	9	Feb. 13[b]	97.53	121	16.46	September	1.43	June	162.2	235	68	51	246	May 1	Oct. 28	180	(a)	(a)
Cordova	10	38.7	−1.4	74	July 24	−2	Mar. 16	155.87	111	28.27	October	3.47	do	158.2	200	137	78	150	May 20	Oct. 1	134	(a)	(a)
	11	41.5	+1.4	79	Aug. 21	2	Jan. 1	159.08	117	37.04	do	2.69	August	109.8	199	109	70	186	May 7	Sept. 24	140	(a)	(a)
Chitina	6	28.5	+.4	86	July 24	−40	Feb. 9	10.81	94	2.81	August	.06	March	64.0	87	148	113	103	May 24	Aug. 30	98		
	7	31.3	+2.7	88	July 16[b]	−46	Jan. 2	11.41	91	2.18	November	.08	June	75.8	80	158	128	79	May 20	Sept. 18	121		
Kennicott	7					−27	Feb. 27	24.25	134	6.03	August	.45	March	105.0		[c]122	[c]103	[c]102	June 12				
	8	29.4	+1.0	79	July 16	−33	Jan. 2[b]	19.38	102	4.43	September	(d)	April	117.1	52	[e]166	[e]66	[e]89	June 4	Sept. 17	105		
Valdez	12	35.9	+.5	75	July 24	−10	Dec. 31	48.38	93	9.34	October	.51	June	225.5	170	115	55	195	May 24	Sept. 1	99	(a)	(a)
	13					−12	Dec. 19	64.86	123	18.60	September	.33	May	261.2					June 27	Sept. 24	89	(a)	(a)
Seward	6	40.9	+2.2	78	July 17[b]	4	Dec. 8	85.56	133	33.17	October	.98	do	134.6	148	119	15	231	May 5	Sept. 27	145	(a)	(a)
Anchorage	7	33.4	+.9	80	July 26	−22	Jan. 28			3.60	July			60.3		[c]103	[c]100	[c]154	May 25	Sept. 1	99	Apr. 1	
	8	36.3	+3.2	82	Aug. 22	−17	Jan. 21	15.17	99	5.09	September	.08	May	62.5	108	88	65	212	May 18	Sept. 18	123		
Talkeetna	5	32.9	+.3	87	July 25	−31	Dec. 30			11.68	July	.22	do	104.6		107	77	181	(f)	(f)	(f)		
	6	34.7	+1.9	90	July 24	−32	Jan. 27	25.16		8.62	September	.13	April	136.0	92	103	54	208	June 26	Aug. 14	49		
Nenana	6	26.8	+.7	81	May 29	−41	Feb. 7[b]	13.52		7.10	July	.17	March	28.6	93	100	82	183	May 23	Aug. 29	88		
	7	29.0	+2.5	90	July 27	−45	Jan. 26[b]	6.64	56	1.76	June	0	July	43.0	52	179	79	107	June 1	Aug. 30	90		
Fairbanks	17	26.0	+.4	86	May 29	−39	Dec. 27	11.82	101	5.39	July	.10	April	34.5	82	93	92	180	(f)	(f)	(f)		
	18	28.9	+3.4	91	July 7	−47	Jan. 26	9.37	79	1.57	June	.02	do	53.6	89	154	58	153	June 1	Sept. 9	100		
Eagle	21	24.5	+.8	85	May 29	−54	Feb. 7	8.07	74	2.12	do	.07	February	45.5	104	107	55	203	(f)	(f)	(f)	May 15	Nov. 18
	22	26.5	+2.7	91	June 7	−56	Dec. 29	8.79	83	2.67	do	.10	October	56.0	99	126	64	175	May 27	Aug. 30	95	May 10	Nov. 30
Rampart	16	21.1	−1.6	78	Aug. 7	−49	Dec. 31	10.65	107	3.64	July	.09	April	52.2	107	98	89	178	May 23	Aug. 29	98		Nov. 11
	17	24.0	+1.4	91	July 27	−65	Jan. 27	9.33	94	1.79	September	.07	October	79.4	105	111	100	154	June 26	Sept. 23	89	May 17	Nov. 20
Tanana	22	23.8	+1.6	77	May 29	−45	Feb. 6	14.62	117	5.80	July	.11	March	27.1	135	93	127	145	(f)	(f)	(f)	May 18	Nov. 3
	23	25.8	+3.0	87	July 27[b]	−56	Jan. 26	11.92	95	3.48	September	.09	October	84.3	102	134	136	95	June 26	Sept. 2	68	May 14	Nov. 15
Ruby	5			73	July 24[b]					7.42	July								(f)	(f)	(f)	May 19	

Nulato	6	23.6	+1.9	72	June 27	−49	Jan. 6	17.72	106	2.69	August	.04	May	85.7	125	114	90	161	([f])	([f])	([f])	May 23	Nov. 8
	7	25.5	+3.0	84	Aug. 5	−50	Jan. 25	15.10	91	2.90	January	.05	April	95.3	128	120	100	145	May 29	Sept. 17	111	May 17	Nov. 9
Allakaket	14	19.1	+1.3	79	Aug. 7	−59	Mar. 4	14.67	122	4.34	July	([d])	March	47.5	99	141	51	193	([f])	([f])	([f])	May 21	Oct. 21
	15	20.9	+2.8	90	July 29	−69	Jan. 26	14.13	114	3.03	September	.05	November	97.9	75	174	42	149	June 1	Aug. 28	88	May 18	Nov. 30
Holy Cross	20	28.5	+2.2	76	July 24	−35	Dec. 30									104	106	155	June 26	Aug. 29	64	May 23	
	21	30.5	+3.4	84	July 30	−40	Dec. 8			[g]3.63	September	[g] .40	April	152.0		111	101	153	May 27	Sept. 16	112	May 19	
St. Michael	16					−31	Mar. 13												June 3				
	17	29.8	+3.4	72	Aug. 6	−26	Dec. 9												June 1	Sept. 26	117		
Nome	16	25.0	−.1	66	Aug. 20	−33	Feb. 5	29.49	165	6.20	July	([d])	March	75.3	148	102	48	215	June 19	Aug. 4	46	June 18[h]	Oct. 24[h]
	17	27.4	+2.2	77	July 31	−40	Jan. 24	17.10	98	4.43	September	.06	May	74.6	111	144	54	167	July 12	Sept. 8	58	May 31	Dec. 4
Candle	11																			Aug. 27			Oct. 20
	12	23.0	+2.4	78	Aug. 6	−47	Jan. 27									169	80	116	July 12	Aug. 31	50	May 16	Oct. 18
Noorvik	5			74	July 28					4.82	August	([d])	March						June 11	Aug. 29	79	June 11	Oct. 25
	6	24.3	+3.4	82	July 30[b]	−53	Jan. 25	13.05	83	3.62	September	.23	November	85.4	90	149	85	131	June 10	Sept. 17	99	May 25[h]	Oct. 18
Barrow	10	8.6	−1.5	61	Aug. 6	−45	Feb. 6	7.04	130	2.44	July	.03	May	63.4	87	68	132	165	([f])	([f])	([f])	Aug. 21[h]	Sept. 21[h]
	11	9.2	−.7	73	Aug. 17	−52	Mar. 6					.16	June			109	73	183	July 14	Aug. 31	48	July 28[h]	Sept. 10[h]

[a] River or harbor open throughout year.
[b] Occurred also on other dates.
[c] Record incomplete.
[d] Less than 0.1 inch of rain or melted snow.

[e] 44 days missing.
[f] Freezing temperature recorded each month of year.
[g] Two months missing.
[h] Arrival of first boat and departure of last boat.

NOTE.—Upper line of figures for year 1922; lower line for 1923.

COSTS

TRANSPORTATION AND FREIGHT RATES

OCEAN, RAIL, AND RIVER TRANSPORTATION

Ocean traffic between ports in the United States and the Pacific Ocean ports in Alaska, except ports on Cook Inlet, is maintained throughout the entire year, and the Bering Sea ports are open from early June until late October.

The Government railroad, under the direction of the Alaska Engineering Commission, maintains regular service throughout the year between Seward and Fairbanks over a 470-mile standard-gauge track; a 32-mile narrow-gauge branch connects Happy Station, near Fairbanks, with Chatanika; and a 40-mile standard-gauge branch connects Matanuska with the neighboring coal fields. In 1923 the Alaska Engineering Commission put two river boats in weekly service, during the open season, between Nenana on the Tanana River and Holy Cross on the Yukon River. Privately owned launches ply on the lower Yukon River below Holy Cross and touch points on the various navigable tributaries of the Yukon. The Copper River & Northwestern Railroad operates between Cordova and points along Copper River to Kennicott, a distance of 192 miles.

Before the Government railroad was completed, transportation to the interior districts was via the Yukon River, up from St. Michael, or down from Dawson via Skagway. The upper Yukon River as far down as Rampart is now best served via Skagway, over the White Pass & Yukon Railroad to White Horse, and thence via this company's river boats to Dawson and points down river. These boats go as far as Nenana on the Tanana River. These rivers are open to navigation from the end of May to early October.

Ocean-freight and through water rates to most points on the Yukon River are now higher than during the boom days because of the great decrease in volume of freight handled, lack of competition, and the increased cost of operating the boats. Since completion of the Government railroad, freight rates have been greatly reduced to points along its line and to some of the interior points. Although the rates to points on the Yukon River touched by the two Government steamers are still high, they are, in general, much lower than they would have been had this service not been established. One of the greatest benefits of the Government railroad has been to make many interior districts "all-year" camps. Without this railroad many mining operations in the interior could not continue nor would the large dredging projects under consideration in the Fairbanks district (fig. 1, *33*) be practical.

The tables of ocean, rail, and Yukon River rates were compiled from tariffs for 1923. No changes in the base rates were made in 1924, and no reduction in the near future was anticipated.

Alaska freight rates

Seattle or Tacoma, Wash., to—	Ketchikan	Juneau	Cordova, Valdez, Seward	Anchorage	Bethel	McGrath	Nome (ship's side) [a]	St. Michael	Golovin (ship's side) [a]	York, Deering, Keewalik, Kotzebue [a]
Miles from Seattle	754	1,032	1,603–1,866	2,144	2,170	2,670	2,500	2,620	--------	--------
Coal, sacked, per 2,000 pounds	[b] $4.00	$4.00	$5.00	$6.00	--------	All commodities; to Bethel, $22.50; Bethel to McGrath, $22.50. Rates per ton at ship's option, weight or measure.	[c] $13.65 [d] 15.65	$20.00 23.00	$14.00 17.00	$14.00 17.00
Freight, n. o. s., ordinary General merchandise General groceries	[b] 7.50	8.50	13.00	15.00	--------		[c] 16.00 [d] 19.00	23.50 28.00	17.00 21.00	21.00 29.00
Grain, feed, per 2,000 pounds	[b] 7.50	8.50	12.00	14.00	--------		[c] 15.50 [d] 18.00	23.00 27.00	17.00 21.00	21.00 29.00
Hay, in bales, 22 pounds or more to 1 cubic foot	[b] 11.00	12.00	14.50	16.50	--------		[c] 16.00 [d] 21.00	24.00 31.50	20.00 23.50	24.00 31.50
High explosives, powder	[b] 14.00	14.00	21.50	24.00	--------		[c] 33.00 [d] 35.50	47.50 52.00	40.00 44.50	53.00 60.00
Lumber, common, not over 32 feet long, per 1,000 feet b. m.	[b] 7.00	8.00	15.00	16.50	--------		[c] 21.00 [d] 23.00	28.50 30.50	22.50 24.00	25.50 27.50
Mining machinery, no single piece over 4,000 pounds [e]	[b] 7.50	8.50	13.00	15.00	--------		[c] 13.50 [d] 16.00	20.50 24.50	13.50 17.00	17.50 27.00
Oils, explosive, 110-gallon drum at 24 cubic feet	[b] 7.50	7.50	12.50	14.50	--------		[c] 16.00 [d] 20.00	25.50 31.50	18.00 23.50	21.00 25.50
Oils, fuel, engine, coal	[b] 7.50	7.50	12.50	14.50	--------		[c] 15.00 [d] 18.00	23.00 29.50	16.50 22.50	20.50 25.50
Return freight southbound										
Carriers, empty drums, 110-gallon drum at 24 cubic feet	[b] 3.50	3.50	4.25	4.75	--------		[c] 3.50 [d] 3.50	7.00 7.00	4.50 4.50	4.50 4.50
Ore and concentrates, value not exceeding $60 per 2,000 pounds	[b] 4.00	4.00	4.50	5.75	--------		[c] 7.50 [d] 7.50	[f] 11.00 [f] 13.50	7.50 7.50	-------- 9.00
25 per cent additional for each 100 per cent or fraction over.										

[a] Lighterage from ship's side to shore, $8 to $12 per ton additional.
[b] Commodity rate as specified.
[c] In carload lots.
[d] In less than carload lots.
[e] Additional charge for pieces over 4,000 pounds.
[f] Rate for valuation not exceeding $100 per 2,000 pounds.

NOTES.—All rates in dollars and unless otherwise specified are on basis of ship's option, per ton of 2,000 pounds by weight or 40 cubic feet per ton measurement. Rates do not include charges for handling, wharfage, storage, transfer, lighterage, or other terminal charges, or marine insurance. Average handling and wharfage charges at both ends are about $3 to $4 per ton.

Joint freight tariffs via Anchorage and the Alaska Railroad, 1923, between Seattle or Tacoma and Alaska points

Alaska points—	Talkeetna	Nenana	Fairbanks	Chatanika [a]	Holy Cross [b]	Iditarod	Marshall via N. C. Co.	St. Michael (launch)	Via A. Y. N. Co.			
									Rampart	Beaver	Circle	Eagle
Miles from Seattle	2,256	2,441	2,497	2,522	3,164	3,564	3,299	3,540	2,714	2,889	3,062	3,237
Article												
Coal in sacks:												
C. L., minimum weight 20 tons, class D	$18.00	$24.40	$25.20	$28.60	$29.40	$68.40	$42.80	$49.40	$42.40	$51.40	$57.30	$63.40
L. C. L., class 4	30.40	45.80	48.20	51.80	50.80	89.80	63.80	70.80	63.80	72.80	78.80	78.80
High explosives, caps, fuse, etc.:												
C. L., minimum weight 10 tons, class 1	48.20	72.60	76.40	80.40	77.60	116.60	90.60	97.60	106.20	124.20	136.20	148.20
L. C. L., less than 6 tons [c]	72.40	109.00	114.60	119.20	116.40	155.40	129.40	136.40	142.60	160.60	172.60	184.60
Groceries, mixed, carload lot:												
Minimum weight 12 tons, class 5 [c]	27.80	41.00	41.00	47.00	46.00	85.00	59.00	66.00	59.00	68.00	74.00	80.00
L. C. L., class 1	48.20	72.60	76.40	80.40	77.60	116.60	90.60	97.60	90.60	99.60	105.60	111.60
L. C. L., class 4	30.40	45.80	48.20	51.80	50.80	89.80	63.80	70.80	63.80	72.80	78.80	84.80
Grain, flour in sacks:												
C. L., mixed or straight, minimum weight 18 tons [c]	19.40	27.00	28.20	35.00	32.00	71.00	45.00	52.00	45.00	54.00	60.00	66.00
L. C. L., class 4	30.40	45.80	48.80	51.80	50.80	89.80	63.80	70.80	63.80	72.80	78.80	84.80
Hardware, iron or steel:												
C. L., minimum weight 15 tons, class 3	34.60	52.80	55.60	59.20	57.80	96.80	70.80	77.80	70.80	79.80	85.80	91.80
L. C. L., class 2	40.00	60.80	64.00	67.80	65.80	104.80	78.80	85.80	78.80	87.80	93.80	99.80
Hay in bales, 22 pounds per cubic foot:												
C. L., minimum weight 12 tons [c]	21.40	26.20	27.00	30.20	31.20	70.20	44.20	51.20	44.20	53.20	59.20	65.20
L. C. L., class 3	34.60	52.80	55.60	59.20	57.80	96.80	70.80	77.80	70.80	79.80	85.80	91.80
Lumber, common:												
C. L., minimum weight 20 tons [c]	15.80	20.60	21.20	24.60	25.60	64.60	38.60	45.60	38.60	47.60	53.60	59.60
L. C. L., class 4	30.40	45.80	48.20	51.80	50.80	89.80	63.80	70.80	63.80	72.80	78.80	84.80
Mining machinery, any quantity.[c] Single pieces not over 4,000 pounds [d]	22.00	28.00	30.00	33.00	30.00	69.00	43.00	50.00	46.00	56.00	61.00	67.00
Oils, explosive, fuel, in drums:												
C. L., minimum weight 13 tons, class 5	27.80	41.00	41.00	47.00	46.00	83.00 96.80 [e] 72.00	59.00	66.00	59.00	68.00	74.00	80.00
L. C. L., class 3	34.60	52.80	55.60	59.20	57.80		70.80	77.80	70.80	79.80	85.80	91.80

Return freight												
Used empty oil drums: L. C. L. to Anchorage only [f]	6.80	14.40	15.60	19.00	23.20	35.40	----------	----------	----------	----------	----------	----------
Ore and concentrates in sacks, declared value not over $50 per ton: [g]												
C. L., minimum weight 20 tons [c]	7.20	10.50	12.00	15.70	----------	54.50	----------	----------	----------	----------	----------	----------
C. L., minimum weight 10 tons [c]	9.00	13.75	15.00	18.90	----------	57.75	----------	----------	----------	----------	----------	----------
L. C. L., under 10 tons [c]	10.80	16.50	18.00	22.00	----------	60.50	----------	----------	----------	----------	----------	----------

[a] Includes $3 per ton transfer charge from standard to narrow-gauge track.
[b] All points on the Tanana and on the Yukon Rivers between Tanana and Holy Cross have same rate as Holy Cross
[c] Special commodity rate.
[d] Additional charge made for all heavy pieces weighing over 4,000 pounds.
[e] Special carload commodity rate, minimum weight 20 tons.
[f] No through rate. Rate given is to Anchorage only, to which ocean rate must be added.
[g] Additional charge of 25 per cent for each 100 per cent or fraction thereof of excess valuation declared.

NOTE.—All rates in dollars and cents per ton of 2,000 pounds. Rates via Seward higher on classes 1 to 4. Rates on Tanana, Yukon, Innoko, and Iditarod Rivers effective only during season of navigation until Sept. 1 of each year. All wharfage and handling charges at Seattle or Tacoma, Anchorage, Nenana, and at destination included in rates given.

Joint freight tariffs via Skagway and Yukon Territory, 1923, between Seattle or Tacoma and Alaska points on upper Yukon River

Alaska points		Eagle	Circle	Beaver	Rampart
Miles from Seattle		1,776	1,951	2,124	2,299
Article	Classification				
Coal in sacks:					
Carload	Commodity	$51.00	$56.00	$59.00	$60.00
Less than carload	Class A	74.00	74.00	74.00	74.00
High explosives, caps, etc	1½ class C	157.50	157.50	157.50	157.50
Groceries [a]	Class A	74.00	74.00	74.00	74.00
	Class B	90.00	90.00	90.00	90.00
General hardware, merchandise	Class A	74.00	74.00	74.00	74.00
Lumber, common	do	74.00	74.00	74.00	74.00
Hay and grain	do	74.00	74.00	74.00	74.00
Mining machinery, single pieces weighing not over 4,000 pounds: [b]					
Carload	Commodity	56.00	56.00	58.00	58.00
Less than carload	Class A	74.00	74.00	74.00	74.00
Oils, explosive, engine, etc	Class B	90.00	90.00	90.00	90.00
Oils, fuel, coal oil, etc	Class A	74.00	74.00	74.00	74.00
Return freight to Seattle or Tacoma					
Empty oil drums, containers	½ class A	37.00	37.00	37.00	37.00
Ore and concentrates, value not over $100 per ton.	do	37.00	37.00	37.00	37.00

[a] Also special commodity rates on certain groceries in mixed carload lots from $53 to $65 per ton to Eagle and $62 to $65 per ton to Rampart.
[b] Additional charge made for all heavy pieces weighing over 4,000 pounds.

NOTE.—All rates are for less than carload lots in dollars per ton of 2,000 pounds unless otherwise noted. Wharfage, storage, and handling charges are additional. Class rates apply only from opening of navigation to Sept. 10, 1923; commodity rates until Aug. 5. Carload lots of minimum weight of 20,000 pounds. Carload class rates are the same to all points given and are: For class A, $68 per ton of 2,000 pounds; class B, $80; class C, $92.

Coastwise and river freight rates

From (district and place)—	To—	Distance	Rate in dollars per ton of 2,000 pounds	Remarks
SEWARD PENINSULA		*Miles*		
Nome	St. Michael	120	$20.00	Gas boat via Norton Sound.
	Solomon		10.00	Do.
	Golovin		15.00	Do.
	Teller		15.00–19.50	Gas boat via Bering Sea.
	Deering		27.50–33.00	Do.
	Keewalik		30.00–37.50	Do.
Golovin (ship's side)[a]	Dime Creek		27.00	Gas boat via Koyuk River.
	Council		35.00	Gas boat, horse scows via Fish-Niuluk River.
Teller (ship's side)[a]	Davidson	40	15.00	Gas boat.
INTERIOR				
Nenana	Roosevelt	256	40.00	Gas boat via Kantishna River.
	Lake Minchumina	360	80.00	Do.
	Livengood		180.00	Gas boat and team via Tolovana River.
Koyukuk Station	Bettles	495	50.00	Gas boat via Koyukuk River.
Bettles	Nolan	75	160.00	Horse scow via Koyukuk River.
Holy Cross	Cripple		40.00	Gas boat via Innoko River.
	Iditarod	400	39.00	Steam and gas boat via Iditarod River.
Cripple	Ophir	70	100.00	Horse scow via Innoko River.
Bethel	Akiak		8.00	Steamer via Kuskokwim River.
	McGrath	500	25.00	Do.
McGrath	Tacotna	65	25.00	Gas boat via Tacotna River.
Rainbow	Hope	9	6.00	Gas boat via Turnagin Arm.

[a] Rates include lighterage from ship's side.

Overland freighting rates and distances

From (district and place)—	To—	Distance	Summer		Winter	
			Rate	Means	Rate	Means
Seward Peninsula:		*Miles*				
Nome	Boulder Creek	14	$0.025	Wagon road		
	do		.0125	Auto road		
	Submarine Beach	3	4.00	Wagon road		
	Dexter Creek	8	15.00	do		
	Osborne Creek	11	17.50	do		
	Anvil Creek	4	5.00	do		
	Glacier Creek	9	15.00	do		
Davidson	Taylor Creek	40	.10	do	$50.00	Winter trail.
Candle	Candle Creek	6				
Solomon	Eskimo dredge	5		Tractor road		
	Shovel Creek	10	20.00	Wagon road		
	Big Hurrah Creek	11	25.00	do		
	Canyon Creek	27	80.00	do		
Council	Warm Creek	10	28.00	do		
	Ophir Creek, lower	4	10.00	do		
	Ophir Creek, W. G. Co.	10	10.00	Railroad horse car		
Iditarod:						
Iditarod	Flat	8	20.00	Tram or auto	10.00	
Flat	Willow Creek	7	20.00	Wagon road	20.00	
	Chicken Creek	7	40.00	Wagon		
	Upgrade Assoc	5	20.00	Wagon road	20.00	
	Granite Creek	4	40.00	Wagon	20.00	
	Dredges	1	10.00	Wagon road	5.00	
	Moore Creek	40	.25	Pack horse	.08	Dog team.
Innoko:						
Ophir	Ophir Creek	4	.04	do	.0125	
	Spruce Creek	6	.08	do		Winter trail.
McGrath	Tacotna	18	25.00	Gas boat	.02	Do.
Tacotna	Yankee Creek	14	10.00	Tractor road		
	do	14	35.00	Wagon road	28.00	
	Ganes Creek	19	.08	Wagon	.03	
	Little Creek		.08	Wagon, pack horse	.02	
	Ophir	24	.10	do	.025	
Eagle-Fortymile:[a] Eagle.	Gravel Gulch	11½	.035	Road	.01	
	Dome Creek	38	.10	Pack horse	.03	
	Steel Creek	52	.14	do	.04	
	Jack Wade Creek	67	.19	do	.06	
	Franklin Creek	80	.25	do	.0625	
	Chicken Creek	91	.25	do	.06	
Circle: Circle	Central House	34	.05	Wagon road	.02	
	Deadwood post office.	42	.08	do	.03	
	Miller House	50	.10	do	50.00	
	Eagle Creek	59	.115	Wagon-road trail	.045	
Fairbanks:						
Fairbanks	Ester, Engineer, Goldstream and Pedro Creek.		.01	Auto road		
	Ester, Fox, Gilmore, Ridgetop, Olnes, Eldorado, and Chatanika.	5–32	.002–.05	Narrow-gauge railroad.		
Gilmore	Caribou Creek	90		Tractor road		Tractor sleds.
	Meehan	14	16.00	do		
Rampart: Rampart	Hunter Creek	5	.01	Wagon road	.005	
	do	7	.025	Wagon	.015	
	Little Minook	8	.015	Wagon road	.01	
Hot Springs:						
Landing	Hot Springs	1½	5.00	do		
Slough	Tofty	12	.025	do		
	Woodchopper	17	.03	do		
	American Creek	22				
Hot Springs	Eureka	22	.025	Tractor road		
Tolovana:						
Dunbar	Livengood	65			.05 and .06	Winter trail.
Olnes	do	54			.05 and .06	Do.
Nenana	do	253	.05–.06	Launch and surface tram.		
Ruby: Ruby	Long	29	.02	Wagon road	.02	
	Greenstone Creek	36	.10	Wagon	.03	Winter trail.
	Meketchum Creek	46	.14	do	.04	Do.
	Spruce Creek	48	.16	do	.04	Do.
	Flat and Solomon Creeks.	56	.20–.25	do	.05	Do.
Kantishna:						
Roosevelt	Eureka Creek	35	.05	Wagon road	.10	Dog team.
Kobe	do					
Bonnifield: Hosena	Platte Creek	23		Man, pack horse		
Valdez Creek: Cantwell.	Valdez Creek	65		Pack horse	.10	Winter trail.

[a] Winter rate to Fortymile camps via Fortymile on Staples from 1 to 2¼ cents less than that given above.

Overland freighting rates and distances—Continued

From (district and place)—	To—	Distance	Summer		Winter	
			Rate	Means	Rate	Means
		Miles				
Yentna: Talkeetna	Cache Creek	40	$0.20	Wagon	$65.00	Winter trail.
	All camps except Dollar Creek, head.		.20	do	65.75	Do.
Shushana: McCarthy.	Chisana	100	.25	Pack horse		
	Creeks (various)		.275		.20	Dog team.
Nizina: McCarthy	Dan Creek	15	.06	Pack horse	20.00	
	Chititu Creek	17	.07	do	24.00	

NOTE.—Rates given in cents per pound or dollars per ton of 2,000 pounds. "Wagon road" means road all the way; "wagon" partly road, partly trail.

Under the conditions encountered the combined ocean, rail, and river freight rates to districts can not be considered a severe handicap to placer mining, except possibly when the first equipment and supplies are shipped in.

The average placer mine in Alaska requires from a few tons to not over 25 tons of supplies per season (exclusive of fuel). Some of the larger steam scrapers and hydraulic outfits may require a little more and the dredging companies from 50 to 300 tons per season, including fuel. In the more isolated districts the additional cost of overland transportation, which sometimes doubles and often more than quadruples the freight rates, can readily become prohibitive; it has caused rapid decline in operations and has retarded development. In isolated camps with regular mail service, parcel post, at 12 cents per pound, is much cheaper for small orders than the usual freight rate.

ROADS AND TRAILS

The urgent necessity for improving traffic conditions is one of the best arguments for building more roads and suitable trails. In most districts the bulk of overland freighting must be done in the winter; it is often unsatisfactory but cheaper than summer haulage. On the seaward slope the swampy sections become almost impassable in the rainy season, and in the interior and the Seward Peninsula districts, travel is even more difficult as the surface of the ground thaws.

During its 18 years of existence the Alaska Road Commission has expended about $8,000,000 upon a system of roads and trails, consisting of 1,114 miles of wagon road, 623 miles of sled road, 4,404 miles of permanent trail, and 712 miles of temporary flagged trail.[12]

The funds provided by the Territorial and Federal Governments for roads and trails have not permitted extension and maintenance of this system in keeping with plans outlined by the commission. Early completion of roads under construction between Chatanika and Circle, Talkeetna and Cache Creek, Ruby and Ophir, Tacotna

[12] Report of the Chief of Engineers, U. S. Army, for 1922, part 1, p. 2235, and Report of Board of Road Commissioners for the fiscal year 1922, part 2, pp. 5-101.

and Ophir, Nome and Deering (via the Seward Peninsula Railway route), and Dime Creek and Candle would undoubtedly hasten the development of these important districts. The Seward Peninsula Railway, a narrow-gauge line between Nome and Shelton, a distance of about 90 miles, after being idle for many years, has recently been acquired and repaired by the Territorial Government and turned over to public use in transporting passengers and light freight. Small gasoline-driven cars and light trucks pulled by dogs are privately used for this. The Bureau of Public Roads is now constructing roads in the forest reserves; some of these will be of direct benefit to placer mining.

POSSIBILITIES OF AIRPLANE SERVICE

The practicability of air service in Alaska has been demonstrated by numerous flights of private planes from Fairbanks to various placer camps within a radius up to 250 miles. Distances were covered in two to three hours which would ordinarily require as many weeks. Conditions for operating airplanes and hydroplanes in Alaska are said to be unusually satisfactory, and the early development of this means of transportation is predicted.

COMPARISON OF COSTS BY DIFFERENT METHODS OF FREIGHTING

Freight rates to and between the principal Alaska ports and placer-mining centers by various means of transportation have been shown, for the more important commodities, in the tables.

Distillate and other fuel oils are generally shipped in 55 or 110 gallon steel drums. These drums, empty, weigh 55 and 210 pounds, respectively, and when shipped full are accepted on ocean lines on a measurement basis of 12 and 24 cubic feet each. Where freight rates are based on weight, as on the railroad, an appreciable saving can be made by using the 55-gallon drums. These drums are also handled more easily, and the loss by leakage is therefore lessened. The new I. C. C. 55-gallon steel drums now being used measure 11 cubic feet, weigh less than old-style drums, and are cheaper in first cost.

The steamship lines handle most articles on the measurement basis, whereby 40 cubic feet is considered equivalent to a ton. A cubic ton usually weighs 15 to 30 per cent less than the short ton of 2,000 pounds.

On the Seward Peninsula summer hauling by team over made roads is normally $1.50 per ton-mile; where there are no regular roads, or with cross-country travel, $2.50 per ton-mile. Winter hauling averages $1.50 per ton-mile. Two-horse teams with a driver can be hired for $18.50 to $22.50 per day and four-horse teams for $35 and $40.[13]

[13] From W. J. Rowe, freighter, Nome, Alaska, 1922.

The overland freighting rates are governed by many conditions, and general averages can not be taken. In the interior placer districts summer freighting over wagon roads by team ranges from $2.50 to $4 per ton-mile; where travel is partly without roads, $5 to $10; and by pack horses, $6 to $27. Winter hauling by team and sled is $1.25 to $3 and by dog team $4.

The use of trucks and tractors is rapidly increasing where suitable roads are available, and where it has been adopted it has greatly reduced the cost of overland haulage. Summer hauling by tractor in the Innoko district costs $1 per ton-mile; in the Hot Springs district, $2.50; and in the Fairbanks district, $1.25. These costs are unusually high when compared with the winter hauling of large tonnages by tractor and sleds over well-broken sled roads, as done by some of the larger lode-mining companies. For example, the Treadwell Co., in the Mayo district, Yukon Territory, is reported as now hauling its ore from the mine to Mayo Landing, a distance of about 40 miles, for $7.50 per ton. Six to eight sleds are used, and as much as 60 tons are hauled by one tractor per trip. Before this system was established the winter freighting cost was $35 and more per ton.

LABOR

Placer miners in Alaska are paid a high wage, but usually are employed only three to five months of the year. Including board, which costs $1 to $4 a day, the cost of general labor ranges from $6.50 a day at some of the larger and more accessible camps to as much as $12 at some of the most remote. At a few mines the men board themselves. The old winter scale of reduced wages is no longer in effect.

Wages for skilled mechanics vary so that no average scale can be stated, but, in general, they are higher than for miners. Hoist men or engineers at the drift mines are usually paid the same as general labor. Point men and nozzle men generally receive 50 cents to $1 more per shift, and cooks the same as general labor. Hospital dues, generally $2 per month, are collected from the men by some of the operators in districts where such service is available.

The following table gives the wages and cost of boarding the men in Alaska camps. It does not include dredge labor, which is mentioned under "Dredging."

Underground labor works an eight-hour day and usually two shifts at the larger mines. Ten-hour shifts are general at the open-cut mines, and 10 or 11, and in few instances 12-hour shifts, are worked at mines run by hydraulic systems. When the shifts are longer than those given in the tables, wages are increased proportionately. The size of the operation, the labor, the water supply available, and other conditions regulate the number of shifts which can be worked. At many placers two 10 or 11 hour shifts are the rule, and arrangements are often made to keep some part of the work going between shifts. By using the "swing" shift the operation can be made continuous without the necessity of overtime.

In the larger and more accessible camps there is usually enough labor available, but in isolated camps there is generally difficulty in obtaining labor after the season has started. Some operators give the men a bonus if they remain for the entire season.

In the smaller or more remote districts most of the labor is performed by prospectors and others who live there. The more experienced and efficient of these men usually have their own mines. It is a common practice to form a partnership of two to six to operate a mine, especially if it is a drift mine, and personal interest and efficiency are promoted thereby. Most itinerant labor has not had much experience in placer mining.

Scale of wages and cost of board in Alaska placer camps

District	No. in Figure 1	Wages per shift [a]					Cost of boarding per man per day
		General labor			Skilled labor		
		Wages	Length of shift	Type of mine	Type of labor	Wages	
			Hours				
Nome	1	$5.00-$5.50	10	O	Foreman Pipeman Carpenters	$6.50-$8.00 6.00 7.00- 9.00	$1.90-$2.25
Solomon	2	4.00 5.00	8 10	D O			2.00- 3.00
Council	4	6.00	10	O			2.15- 2.50
Kougarok	8	6.00	10	O			3.00
Fairhaven	7	6.00- 7.00	10	O	Pipeman	7.00- 9.00	2.25- 3.00
Marshall	16	6.00	8	O			2.50- 3.00
Ruby	28	6.00	8	D			3.00- 4.00
Koyukuk Chandalar	13 15	6.00 [b] 10.00	8	O,D			3.50- 4.00
Iditarod	21	6.00- 7.00 [b] 10.00	10	O	Engineers Blacksmith	8.00 9.00	3.00- 3.50
Moore Creek		8.00	10	O			3.50
Innoko	22	6.00- 7.00	10	O	Engineers	8.00	3.50
Rampart	31	5.00 [b] 8.00	10	O			2.50- 3.00
Circle Eagle Fortymile	37 40 41	5.00- 6.00 5.00	10 8	O D	Point men Blacksmith Engineers	6.00 7.00 6.00- 8.00	2.25- 3.50
Fairbanks	33	5.00 6.00	8 10	D O	Point men Blacksmith Engineers	6.00- 7.00 7.00 8.00-10.00	1.75- 2.25
Tolovana	32	5.00 6.00	8 10	D O	Point men	6.00	2.25- 3.00
Hot Springs	30	5.00 5.00- 6.00	8 10	D O	do Pipeman	6.00 6.00	2.00- 3.00
Kantishna	27	5.00	8	O	do	6.00	2.75- 3.00
Yentna	26	6.25	10	O	Blacksmith	6.00	2.00- 2.50
Shushana	46	8.00 [b] 12.00	10	O			4.00
Nizina	47	[c] 5.00	10	O	Foreman Stack man Hoist man Pipeman and powder man.	8.00 5.25 5.25 5.50	1.75
Cook Inlet		6.00	10	O			1.50- 2.00

[a] Board furnished in addition to wages paid, except where especially mentioned.
[b] No board.
[c] Plus bonus of 50 cents per shift given to all employees working entire season.
O, open cut.
D, drift mine.

NOTE.—See also dredge wages.

SUPPLIES

The larger placer concerns purchase virtually all supplies in the United States. Shipments are made in the fall, so as to be freighted to the property during the winter or early in the spring, or, where transportation permits, are made as required. Provisions, hardware, dynamite, and general supplies can be purchased from local merchants in all of the districts. Quantities of used machinery and equipment are available in most of the camps, and, as they can be purchased for a very small part of their original cost, have been the main source of such supply for many years. New machinery and equipment can seldom be obtained locally unless by special order through the merchants. In most coast towns and points on the railroads supplies can be purchased at reasonable prices. In the smaller and more remote districts the prices often are almost prohibitive.

Economic conditions in the United States are naturally reflected in Alaska, and the great increase in the cost of supplies since the World War had a marked effect on operations and development. Prices are now on the decline. Fluctuating prices and varying freight rates to different points make it impractical to give the cost of supplies in Alaska except for those specific commodities cited on the following pages. By consulting outside prices and the freight rates given in this report a close estimate can be made of the cost of supplies landed at the property.

LUMBER AND WOOD FUEL

The best and most extensive forests are in southeastern Alaska, where there are few gold placers. Southwestern Alaska has, in general, a good supply of spruce and hemlock, trees with diameters up to 18 and 24 inches at the butt being quite common. In the Tanana Valley and its tributaries around Fairbanks there are growths of spruce, with some birch and cottonwood. Most of the interior districts drained by the tributaries of Yukon and Kuskokwim Rivers have fair supplies of timber.

Earlier mining operations, especially in those districts where extensive drift mining has been done or where large quantities of wood have been used for steam thawing and power, have almost stripped near-by forests, so that now it often becomes necessary to bring wood from distant points, thereby greatly increasing its cost.

With the exception of small spruce timber east of the Council district (fig. 1, *4*) and around Dime Creek in the Koyuk district (fig. 1, *5*), Seward Peninsula has to depend on outside sources. Sawmills are at work in most coast towns and larger interior centers. Many of the larger hydraulic companies have their own sawmills. Most lumber and mine timber is native spruce. Birch is better than spruce for fuel, although both are used. Native spruce lumber is used for sluice boxes, although clear wide boards are generally difficult to obtain; much of it is 10 inches or less wide, is full of knots, and warps badly. However, it does not split as easily as outside lumber. In some of the remote districts lumber is whipsawed by hand at a cost of $100 to $150 per thousand board feet, which is often much cheaper than the cost of freight from a distant source.

Logs, mining timber, and wood are generally procured under contract, although many mine operators cut their own supply and haul it during the winter. The cost of cutting small spruce wood is generally $5 to $7 per cord for 4-foot wood and $3 to $5 for 16-foot wood. The latter is later cut by power saws at the camp as needed. Haulage is often the largest item of cost. On Goldstream Creek near Fairbanks, where there is a good supply of fairly large timber, the contractors agree to deliver 4-foot spruce and birch wood alongside the railroad track for $7.50 per cord. Forest fires are frequent during dry seasons in the interior, destroying much timber and seriously menacing the community.

Average dry native lumber weighs about 3,000 pounds per thousand board feet. Lumber planed on one side and two edges costs $25 to $50 more per thousand than rough lumber. Some operators buy rough lumber and dress it by hand. Lumber that has to be hauled long distances will cost as much as $200 to $250 per thousand board feet landed at the property. On Dan Creek spruce lumber was at one time produced in the company's mill for $25 per thousand, and a few years later, when it was difficult to obtain suitable logs near by, the cost of the lumber was $45.

The following are average prices in the Fairbanks district (fig. 1, *33*) for spruce timber delivered to properties within a mile of the railroad: 40-foot poles, 2½ to 5 inches diameter, $9 per cord; 16-foot poles for drift-mining timber, 4 to 6 inches diameter, $12 per cord; 12-foot timber, 12 inches diameter, $1 each; 60-foot gin poles, $60 each.

The accompanying tables have been compiled to show the cost of wood and lumber in some districts. As supply, hauling rates, and numerous other conditions affect these costs, there are bound to be many exceptions. The examples given are selected, as they show the general maximum and minimum costs. The cost of lumber is for native rough-sawed, except where otherwise noted.

Cost of wood

District	No. in Figure 1	Price per cord	District	No. in Figure 1	Price per cord
Koyuk	5	[a] $15–$16	Circle	37	$5–$14
Marshall	16	[b] 14– 15	Fairbanks	33	10– 14
Ruby	28	8– 12	Tolovana	32	10– 12
Iditarod	21	18– 26	Hot Springs	14	[c] 16– 18
Innoko	22	9– 20			

[a] Dime Creek. [b] Willow Creek. [c] Nolan.

Cost of lumber

Sawmill or supply point	Nearest district in Figure 1	Price per 1,000 b. m. feet	Sawmill or supply point	Nearest district in Figure 1	Price per 1,000 b. m. feet
Nome	1	[a] $100	Hot Springs	30	$40
Ruby	28	40	Kantishna (Glacier Creek)	27	80
Iditarod	21	75	Seward	51	40
Flat	21	100	Cordova	52	36
McGrath (Medira)	20	85	Talkeetna	26	45
Tacotna	22	100	Fortymile (McKinley Creek)	41	100
Fairbanks	33	45	Circle (Miller House)	37	80
Livengood	32	100	Circle (Miller House), dressed	37	125

[a] Outside supply.

COAL

The use of coal for steam raising at placer mines is practically confined to a few steam-scraper mines and small drift-mining operations in the Fairbanks district (fig. 1, *33*) along the Government railroad. Lignite can be delivered at those properties for $6 to $8 per ton and Matanuska bituminous coal for $10 to $12 per ton. Use of these fuels in placer mining is practical only for a mine within close hauling distance of the railroad, coal mine, or shipping point where they can be cheaply purchased. In the Fairbanks district, where these conditions prevail, their use will no doubt be extended.

Extensive coal fields are widely distributed in Alaska.[14] Good bituminous coals are mined in the Matanuska field, about 50 miles northeast of Anchorage, and in the Bering River field, about 20 miles inland from Katalla. Lignite is mined at several places in the Nenana or principal interior coal field. A good bituminous coal is found near Cape Lisbourne, about 200 miles north of Nome, and at different times small shipments have been made to Nome, but the field has not been exploited further. In the Yentna district (fig. 1, *26*) the Cache Creek Dredging Co. used for its dredge a lignite mined close by, but it was unsatisfactory. Lignite is also found at numerous other places along the Pacific coast, in the Yukon River Basin, and on Seward Peninsula, where small quantities have been mined at different times.

[14] Brooks, A. H., "Alaska coal and its utilization": Mineral Resources of Alaska, 1909: U. S. Geol. Survey Bull. 442, 1910, pp. 47–100.

Although coal from many different sources has been shipped to Nome, virtually all of the supply now comes from British Columbia. This coal is shipped in sacks and sells for $36 per ton during the summer season and $39 in the winter. Healy River lignite sells for $3 per long ton in carload lots at the mine, $4.50 per short ton in the cars at Fairbanks, and $6.50 at Anchorage. Bituminous coal from the Matanuska field sells for $6.50 to $7 per ton at the mine and $8 on the cars at Anchorage. One ton of lignite is equivalent in heat units to about 1 cord of spruce wood.

OIL FUELS

Gasoline, distillate, crude oil, and Diesel oil now supply the power for most of the dredges. The Nome and other Seward Peninsula districts rely entirely on such fuel for power. In 1922 gasoline sold at Nome for $5.65 per case and distillate for $4.85. Most operators who use oil get their supply from Seattle. Shipments are made in drums, and after freight, lighterage, depreciation, and return freight on the drums were paid the 1922 shipments of Diesel oil, 24° gravity, cost 25 cents per gallon and distillate 39 cents, landed in the warehouse at Nome. A large dredging company at Nome is now having oil shipped in tank boats. One large oil company has established a station at Seward, where Diesel oil of 24° gravity was quoted during September, 1923, at 3 cents per gallon higher than the Seattle price. At Fairbanks, this oil, landed in drums, cost 22 cents per gallon. Details on drum containers and freight rates are given under "Transportation and freight rates."

A high-gravity paraffin-base oil is being produced and refined in small quantities at Katalla; practically all of it is used locally. Drilling is under way at Cold Bay, where the geological conditions are considered favorable for oil. Oil seepages and favorable geological formations are reported at many places in Alaska.[15]

PROSPECTING

The necessity for thoroughly prospecting a placer property before much money is invested in mining equipment can not be too strongly emphasized. Most failures in placer mining have been due either to lack of careful prospecting or to incorrect interpretation of prospecting results. A mining property attractive enough to equip with a plant should certainly be worth prospecting. If preliminary investigation shows that further work is justified, an attempt should be made to develop a large enough area of profitable ground to justify equipping the property. In the days of high-grade deposits,

[15] Martin, G. C., Preliminary Report on Petroleum in Alaska: U. S. Geol. Survey Bull. 719, 1921, 83 pp.

when the margin of profit was usually large, thorough prospecting was not considered important in many places. The remaining deposits have mostly been selectively mined, leaving isolated areas of unworked ground which make careful prospecting even more necessary than in unworked areas. Some deposits can be easily and cheaply prospected by the average miner, but for most of the remaining known placer ground skill and experience are necessary, especially when the gold content and the volume of large areas of low-grade material should be accurately determined. With proper prospecting and correct interpretation of the results, the true character of the deposit is determined and a close estimate can be made of the total amount of gold present in the deposit.

The accuracy of the results from prospecting is governed mainly by the character of the deposit, the distribution of the gold, the equipment available, the amount of prospecting done, and the experience, honesty, and judgment of the man in charge. The more important factors to be determined are the extent, depth, volume, and gold content of the deposit; depth and character of the overburden and gravel; distribution and character of the gold content, bowlders, clay, and frost; and the character and contour of bedrock. Placer deposits are prospected with shafts, adits, open cuts, and drill holes. Where the condition of the ground permits, shafts or open cuts are generally the most practicable means for the average Alaska miner. Drilling is very satisfactory for most deposits, especially for the deep deposits or for ground where excess water prohibits the use of shafts and open cuts.

Alaska prospecting methods in unfrozen ground differ but little from those used in other countries. In frozen ground, however, different conditions are encountered, and prospecting methods specially adapted to such ground are used.

REVIEW OF PROSPECTING METHODS

The choice of a method for prospecting placer ground is discussed by Hutchins,[16] as follows:

> Without regard to the geology, all Alaskan placers may be classified as shallow or deep. For convenience of consideration in this paper all placers less than 25 feet deep are arbitrarily called shallow. Such placers, at or near sea level, if so wet as to require pumping, can be investigated with shafts while the pump is set on the surface of the ground. The practical limit of suction at sea level is about 25 feet. Placers deeper than 25 feet or of less depth and at higher altitude, if wet, must be drained by sinking pumps to the necessary depth. This necessitates a larger shaft to accommodate the pump, pipes, etc., and obviously will increase the cost per foot.
>
> The choice of prospecting method is governed by a number of considerations, some of which are influenced by conditions foreign to the actual prospecting.

[16] Hutchins, J. P., "Prospecting and mining gold placers in Alaska"; Mineral Resources of Alaska: U. S. Geol. Survey Bull. 345, 1908, pp. 54–77.

For instance, a deposit well adapted to investigation by the steam drill may be so inaccessible as to make it good practice to use hand drills or shafts instead. The rapidity, cost, and accuracy are the governing factors in making a choice of method. Many deposits have features that make one method particularly applicable. In some places conditions are such that either the shaft or the drill method may be employed with equally good results; both may be used advantageously. The frozen condition of many of the Alaskan placers makes it possible to use the shaft method in alluvium which, if unfrozen, could be tested by shafts only at a large cost for pumping and timbering.

Where shallow narrow creek beds are to be prospected, it is often good practice to make open cuts clear across the bed, or far enough to delimit the pay streak. Such creeks generally have extremely irregular pay streaks, and cuts of this character would determine the distribution of gold content with thoroughness. Work like this may be costly, but the compensating advantages often justify it.

In a shallower placer less than 10 feet deep and containing no water, or so little water that it can be easily bailed, prospecting can generally be more cheaply and rapidly done with shafts or open cuts than with drill holes sunk with a steam churn drill. Material can be thrown out of a shaft 10 feet deep, and no timbering is ordinarily required if the shaft is kept free of water during the sinking. Only one man per shaft is required if there is only a small amount of bailing and if the gravel is unfrozen and easily broken down. * * *. Under such conditions the steam churn drill is at a disadvantage, for much time may be consumed in frequent moving from hole to hole. This is particularly true if the surface is so rough or marshy as to make moving difficult. The hand drill, being more mobile, can be used advantageously in such shallow gravels, where it can generally drill 25 to 40 feet or more per day. * * *.

If the alluvium to be tested has a depth of about 25 feet and is so wet as to require a steam pump, drill methods are more applicable than shafts. Such unfrozen gravel is generally loose or becomes loose on exposure to the air or by reason of water running into the shaft. Shaft sinking will be slow and costly, as close timbering and breast boarding or sheet piling may be necessary. Samples taken under such conditions are likely to be inaccurate, for running ground may enter the shaft. The fact that the material from the shaft is shoveled under water, possibly from a rough bedrock or from a soft bedrock, which may become sticky by reason of the man puddling it as he works, also introduces inaccuracies. * * *. Under such conditions the churn drill method is preferable. The circumstances that cause a low and costly progress and inaccurate sampling with shafts have no bad effect on steam or hand churn drills. In general, where the gravel is dry, as accurate or more accurate sampling can be done with shafts as with drill holes, but the presence of water in such volume as to require pumping makes drilling preferable.

It is good practice to use both drill holes and shafts, the idea being to use enough shafts to allow inspection of the physical character of the gravel, bedrock, etc., and to depend on the drill holes for the determination of the tenor, extent, and thickness of the gravel. * * *. The peculiar conditions of the alluvium under consideration must therefore be the determining factor.

The irregularity of gold distribution in the alluvium of Alaska makes careful prospecting necessary in order to determine the limits of the pay streaks. Many samples may thus be needed. As a general rule, drill holes are better suited to this work, for they can ordinarily be sunk more rapidly and more cheaply.

Where bench gravel is to be tested, cuts can be easily made. Vertical sampling is thus done, and this method has been used with good results. It is assumed that gravel in the same stratum or at the same perpendicular height above bedrock has the same general tenor and characteristics.

Prospecting has so far in this paper been treated as the obtaining of samples merely. Sometimes it may be conducted as a working test. This is particularly applicable where there is an available water supply. Thus cuts may be ground-sluiced through bench gravel and considerable amounts of material washed. Such cuts also permit subsequent sampling of the gravel section to good advantage. Inasmuch as this is a working test, data relative to operating cost may thus also be obtained.

A governing factor in the choice of the prospecting method is the kind of information that is required. Thus, in testing alluvium thought suitable for hydraulicking or dredging, information concerning the section from grass roots to bedrock is desired, and generally this can best be obtained by sinking shafts or drill holes. In testing alluvium for drift mining little information is required in regard to any of the gravel section, except that adjacent to bedrock. Openings that follow this lower stratum will, of course, give a maximum of information with a minimum of excavation.

Prospecting can be done at all times of the year; in fact, winter is often the more favorable season. Shaft sinking can often be done best during the winter, especially in wet deposits which may drain or be frozen during the cold months. Likewise, marshy areas or creek bottoms can be tested more easily in winter, because heavy drills can then be readily moved without miring, and it is easier to drill a stream bed from the ice. Unless the weather is unusually cold, as it may be during several of the midwinter months, drilling during the winter can be conducted readily if steam is available and a heated shelter is provided.

SHAFTS AND DRIFTS

The usual small prospecting outfit for sinking shafts in frozen ground consists of a 4 or 6 horsepower boiler mounted on a sled or skids, a steam point or pipe, steam hose, and a hand windlass. Such an outfit costs $300 to $500 when new, but secondhand outfits can be purchased for $100 to $200. Two men are employed, one on the surface and one in the shaft, which is generally made 36 to 42 inches in diameter, or just large enough for a man to work in.

Methods of thawing and sinking such shafts depend on the character of the deposit. Frozen muck (organic matter, sand, and silt cemented by ice) can be readily picked, but it is customary to thaw all material. Some miners thaw only a few feet at a time, as the shaft is deepened. Frequently a 3/8 or 1/2 inch pipe is slowly driven and thawed to bedrock or is inserted in a drill hole, steaming the ground at the rate of 30 to 45 minutes per foot of depth. Practice also varies according to the character of the ground encountered.

The practical limit of depth at which one man can handle a windlass is about 75 to 80 feet; for greater depths a steam hoist is required.

In drift-mining camps where standard steam equipment is available the shafts are often made large enough for later use as working shafts if pay dirt is found. As a rule, the spacing of prospect shafts is irregular, rarely being as close as that of drill holes. In deep frozen ground the prospect shaft is usually sunk where "pay" is expected, and when bedrock is reached prospecting may be continued by drifts and crosscuts. Shafts in shallow wet ground can often be dug during the winter by "freezing down." The shafts are then dug to water and allowed to freeze. The frozen material at the bottom of the shaft is then carefully removed, and the process is repeated until bedrock is reached. This method is slow, but one man can handle a number of shafts, and it is generally cheaper and more accurate than sinking through live water. A successful method used in sinking shafts in some wet loose gravel of shallow depth was to sink and "crib" timber to the water level. From this point a 5 to 10 foot length of large-diameter steel pipe (42 to 50 inches) was readily sunk to bedrock.

COST OF SINKING SHAFTS AND DRILL HOLES

The cost of prospect shafts is $2 to $8 per foot for average conditions, but ranges from 50 cents to $1 for pits 4 to 8 feet deep to more than $15 per foot for some of the larger, deeper shafts in adverse or difficult ground. Some examples are presented below. Details on such shafts and drifts are presented under "Drift mining."

Cost of prospect shafts, pits, and drifts

District	Size	Depth	Ground	Timbered	Cost	Drifts	
						Size	Cost
Nome district:	*Feet*	*Feet*			*Per foot*	*Feet*	*Per foot*
Submarine beach	3½ by 3½	30–50	Frozen	No	$3.50	6 by 6	$4.00
Third beach		40–50	do	No	2.00		2.50
Do	4 by 5	90	Partly frozen	Imported sawed lumber.	8.00		
Ophir Creek	3 by 6	5–14	Not frozen	No	1.75		
Kougarok River		5–6	Frozen	No	.65		
Iditarod district:							
Otter Creek	(a)	14–17	Frozen gravel	No	4.00		
Willow Creek	(a)	16–18	Frozen muck and gravel.	No	3.00		
Ruby district	4 by 6	80	do	No	6.00		
Fairbanks district:							
Goldstream Creek.	5 by 7	20–22	Partly frozen[b]	Upper 5 feet	2.50		
Do	4 by 6	100	Frozen	Upper 20 feet	8.00		
Interior districts	Large	Deep	do	Cribbed in places	6.00–15.00	(c)	4.00–8.00

[a] Forty-two inches in diameter. [b] No thawing required. [c] Not timbered.

In prospecting by shaft, all the gold-bearing gravels should be sampled in sections, so that the horizontal distribution of the gold can be definitely ascertained. Not only should the walls of the shaft be carefully sampled, but where water is available it is good practice to sluice all the material excavated. The large samples so obtained are one of the chief advantages over prospecting with drill holes. The material from an average shaft has about 50 times the volume of that from a drill hole of similar depth made with the standard 6-inch drill, yet there are numerous instances of prospect shafts or open cuts being sunk and only a few pans of material taken for a sample.

PROSPECT DRIFTS

Prospecting and sampling for drift mining involve special consideration, as only the richer ground is mined. The drift face is usually 5 to 6 feet high and includes 4 to 5 feet of gravel and 1 to 2 feet of bedrock. In prospecting channel deposits that are deeply covered, a drift is driven along the old stream bed and crosscuts are turned off from this. As work proceeds vertical samples are taken at intervals along the face. Both bedrock and roof are tested, so that no pay will be overlooked. The samples are panned, and sometimes the gold is weighed; more often an experienced miner estimates it. A check is sometimes made by panning a single wheelbarrow load from the face, or every tenth wheelbarrow load is panned or rocked, or the accumulated amount is sluiced as one sample.

Drift miners have different ways of calculating the results of sampling, although their methods are generally based on the value of the gold in cents per square foot of bedrock. In the Seward Peninsula the cubic yard is often used. Other units employed are the values of the gold per pan, wheelbarrow, car, or bucket. If the thickness of the pay mined and the value of the gold per pan are known, the calculation is made as follows: Cents of gold per pan times the number of pans to the cubic foot times the thickness mined in feet equals the value of gold in cents per square foot of bedrock area.

Seven pans of gravel are usually taken as equal to 1 cubic foot of material in place, although some persons figure 5 or 6 pans to the foot. Usually one heaping load on a No. 2 round-nosed shovel is considered a panful, and seven shovelfuls closely equal the cubic foot. The average wheelbarrow load contains 12 to 14 pans or approximately 2 cubic feet, or there are 11 to 14 wheelbarrow loads per cubic yard. In the Fairbanks and other interior districts 7 pans to the cubic foot or 189 pans to the cubic yard is the scale generally used; in the Seward Peninsula the average is about 170 pans and in other places as low as 135 pans. Such variable and approximate units are conducive to misleading results, but an experienced miner can usually estimate with fair accuracy. Many failures result from overestimates, which are often due to improper sampling. Often the surface of the bedrock is very irregular and the distribution of the gold is spotty. In many placers the gold is chiefly found on the rougher or higher parts of the bedrock, and unless such conditions are understood and the deposit is carefully prospected disappointment is bound to result.

PROSPECT DRILLING

Drilling in unfrozen ground and the calculation of the results follow general practice, as described in the literature of drill manufacturers. The prospecting of dredging ground has been covered by Janin [17] in a thorough and satisfactory manner.

Partly frozen ground is the most difficult and hazardous to drill, for the holes must always be cased, and much of the drilling must be done ahead of the drive shoe, a procedure leading to inaccuracies.

In frozen ground special methods are required. If the ground is frozen solidly, it generally is unnecessary to case the entire hole. A short length of pipe at the top seals off any surface water. A little water is poured in, and 5 feet or more is drilled each time before pumping. When pay is reached, the drilling interval should be reduced to 1 foot or so, and water should be used sparingly or an irregular hole will result. When casing is used and it freezes to the hole, warm water or steam is turned in to loosen it.

In addition to making the customary measurements of the core, the careful driller pumps all water from the completed hole and runs in measured volumes of cold water, usually 5 gallons at a time; after finding the depth to the surface of the water he adds another measured amount and determines the new water level. When the amount of water added each time and its displacement are known, the volume of each section can be accurately checked. Unless some similar check is made, drilling without casing is hazardous practice, for material may slough off the sides of the hole and thus cause errors in estimates of gold content.

SPACING AND MEASUREMENT OF HOLES

Close spacing of drill holes is imperative in most Alaska creek placers, especially in rich deposits, because of possible narrow pay channels or the erratic distribution of the gold. A spacing of more than 100 feet across the channel can seldom be relied on. On the

[17] Janin, Charles, Gold Dredging in the United States: Bull. 127, Bureau of Mines, 1918, pp. 26–53.

tundra and at other places near Nome, holes are often spaced about 200 feet apart in rows 400 feet apart. In average shallow creek dredging ground the holes may be 25 to 50 feet apart, in rows 500 to 2,000 feet apart. The procedure depends on the results, and intermediate holes and rows may be drilled. In unusually spotty, shallow ground containing coarse gold, as on Ganes Creek (fig. 1, 22), a spacing as close as 12 feet, with rows 20 feet apart, has been used without a constant average being obtained.

TYPES OF DRILLS USED

Hand-operated drills are now seldom used in Alaska; they have been replaced by steam and gasoline driven drills of 4, 5, and 6 inches diameter, the size and type of drill depending on the locality and the character and depth of the ground. The heavy 6-inch steam traction drill has been largely used in the deeper ground and where difficult conditions are encountered. These heavy drills, fully equipped, weigh 8 to 10 tons and cost $4,000 to $5,000. Light 4-inch gasoline drills, of several different makes, weigh 1,000 to 3,500 pounds with full equipment and cost $900 to $1,300.

STEAM DRILLS

Heavy steam drills make holes more rapidly than the lighter types but are difficult to move over rough or swampy ground; under such conditions the smaller and lighter gasoline drills often make more footage in a given time. A drill, known as the Brower drill, specially built to meet such conditions has been in service near Nome for 18 years (fig. 2). It is a reconstructed No. 5 Keystone drill equipped with an 8-horsepower gasoline engine and has a special double-chain drive to the front wheels. It can travel 4 miles per hour and climb a 45 per cent grade. The wheels are made of 6 by 8 inch timber and are shod with heavy chains, the rear wheels being 4 feet high and 2½ feet wide and the front wheels 5½ feet high by 5 feet wide. Special appliances are provided for operating the jars and pulling casing. Under average conditions the drill can leave a set-up, move 200 feet, and be drilling again in 30 minutes. In setting up the wheels are blocked and the drill carriage leveled and swung into place with jackscrews. Double, extra-heavy 6-inch casing, generally with flush joints and inside couplings, is used with a 7⅜-inch shoe when ground is not frozen. The drill crew consists of one drill man at $8 and a helper at $5 per eight-hour shift. One or two panners are used who are paid $7 per shift.

Costs with Brower drill.—The Brower drill has been used for contract drilling. The average contract price in frozen ground without casing, with everything except the panners provided, was 75 cents to $1 per foot; and in thawed ground, up to 50 feet, $1.25 to $1.50 per foot; 50 to 75 feet, $2.50; 75 to 100 feet, $3; more than 100 feet, $4. The drill averages about 80 feet per 10 hours in deep frozen ground, or two 55-foot holes in 12 hours; and in thawed ground, 35 to 40 feet per 10 hours.

CHURN DRILL

With the 6-inch churn drill a 5⅝-inch chisel bit is generally used for drilling frozen ground; it should cut a smooth straight hole about 7 inches in diameter. Rapid progress can be made where the deposits have a deep covering of muck or barren material.

FIGURE 2.—Prospecting by drilling; old Brower drill near Nome

The average cost for drilling Alaska placer deposits with a 6-inch churn drill is $2.50 to $5 per foot. In recent prospecting of dredging ground in the Fairbanks district the average cost of prospect shafts was $5.50 per foot, and of drilling both cased and open holes $3.25 per foot, including the panning. Shafts and drill holes were spaced 25 feet apart on the rows and the rows spaced 2,000 feet apart. The ground was 18 to 40 feet deep, and most of it was frozen.

CONTRACT DRILLING

In some districts drilling can be done by contract, although there are few contractors now in the business. In the Fairbanks district contract drilling in frozen ground 150 to 200 feet deep, mostly muck, has been done for $1 per foot, excluding fuel. In the same district a drill and crew can at times be hired at $50 per nine-hour day, and again a drill alone has been rented for $10 per day. In the Ruby district some contract work was done for $1.50 per foot in frozen muck and $2.50 in frozen gravel of any depth.

GASOLINE DRILLS

A very light 4-horsepower gasoline drill using 4-inch casing is popular in the Seward Peninsula for preliminary tests of unfrozen light shallow gravels, up to 15 feet deep, underlaid by soft bedrock. Such a drill has also proved successful in testing ahead of dredges. Although it can be used as a churn drill, more often the pipe is driven to bedrock without pumping. The pipe is then pulled and the core removed. Such a procedure usually returns a low percentage of core, so that the results of such drilling should not be relied on too strongly. The entire outfit weighs but 1,000 pounds;

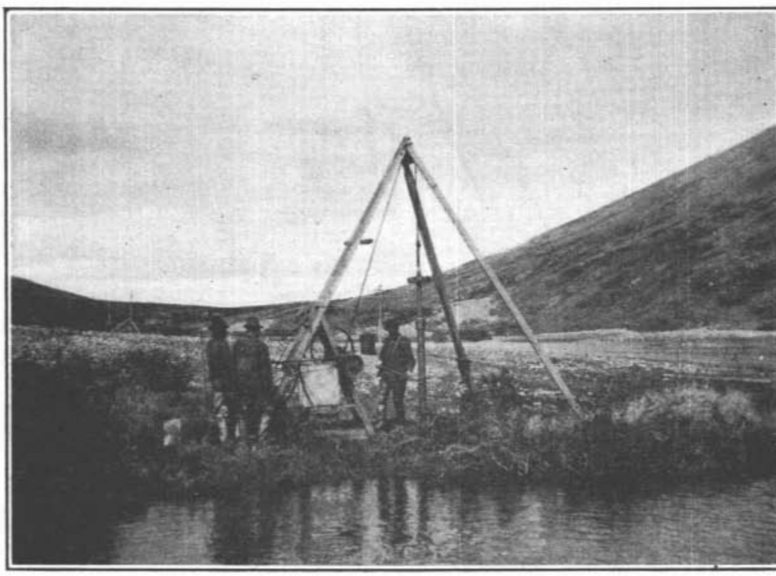

FIGURE 3.—Drilling shallow ground with 4-inch drill driven by gasoline engine

as it is mounted on two wheels, which are detached when the drill is in use, it can be easily moved (fig. 3). Three men, including the panner, constitute the crew. From 60 to 75 feet of drill hole can be made per 10-hour shift.

WATER SUPPLY

In placer mining the water supply is of utmost importance, as it must be ample for the required output and be available at the property under conditions best suited to the system of mining used. Water supply is governed by different factors; aside from economic factors, the most important are precipitation, temperature, topography, vegetation, and evaporation. Although all forms of placer mining require water, to obtain water for small mines that do not use water under pressure is generally not especially difficult. The problem of a water supply for use under pressure is therefore discussed in more detail here.

On the south and west slopes of the Alaska Range conditions are most favorable for comparatively large, steady supplies of water. Most of the drainage basins are above the general level of the mines, so that water for mining may be made available by comparatively short ditches or pipe lines. Annual precipitation is heavy, and seasonal temperature variations are seldom extreme. In the Nizina, Chistochina, Girdwood (fig. 1, *47*, *44*, and *49*, respectively), and other districts many streams are fed by glaciers or snowcaps and maintain a constant or increased flow during the dry summer months, when most Alaska water supplies are low.

The Yukon-Tanana or interior regions are dissected uplands, and the predominating features are series of long branching ridges of uniform elevation. Natural storage basins are generally lacking, the drainage basins or catchment areas above the diversion point of the stream are small, and the streams have uniformly low gradients. As a rule, the precipitation is considerably less than in other parts of Alaska and the summer temperatures are higher. Rapid melting of the snow, frozen ground, and sparse timber cause a rapid run-off and a widely fluctuating stream flow that depends almost directly on the precipitation. Conditions in the interior districts, therefore, are not generally favorable for obtaining satisfactory water supplies.

Most of the Seward Peninsula is rugged and much dissected by streams. The precipitation is greater and the temperature lower than in the interior of Alaska. The mountains in the central part of the peninsula receive the heaviest precipitation, and many peaks are covered with perennial snow. Catchment areas are generally large and are situated at elevations well above the point of diversion; there are some good natural storage basins. Most of the important placers, however, are far from the diversion point; hence long expensive ditches and pipe lines are necessary.[18]

METHODS OF MEASURING FLOW OF WATER

MINER'S INCH

The unit of water measurement ordinarily used for all classes of work is the "second-foot," and from it the quantity expressed in other terms may be obtained. It is the unit for the rate of flow

[18] For further information on water resources consult the topographic maps and water-supply papers of the U. S. Geological Survey and the climatological data issued by the U. S. Weather Bureau at Juneau.

of water moving in a stream 1 foot wide and 1 foot deep at the rate of 1 foot a second. This unit, however, is seldom used by Alaska placer miners, who are more familiar with the "miner's inch" and the "sluice head."

The "miner's inch" expresses the rate of flow and is applied to the volume of water flowing through an orifice of a given size with a given head. The head of the water and the size of the orifice differ in different States, where they are defined by the law. The California miner's inch is now the one in most common use and was defined by an act approved March 23, 1901, as follows: "The standard miner's inch of water shall be equivalent or equal to 1.5 cubic feet of water per minute, measured through any aperture or orifice." This miner's inch corresponds to the so-called "6-inch head" and is equivalent to one-fortieth of a second-foot.

Experiments made in California by A. J. Bowie, jr.,[19] to determine the volume of the miner's inch—defined as $\frac{1}{200}$ part of the quantity of water which would flow through an opening 12 inches high by 12¾ inches wide in a 1½-inch plank, under a constant head of 6 inches above the top of the discharge—showed that 1 miner's inch equaled a discharge of 1.4994 cubic feet per minute. For all practical purposes this may be taken as equivalent to 1.5 cubic feet, or 11¼ gallons of water per minute; in other words, 1 cubic foot per second equals 40 miner's inches. A miner's inch is so interpreted and used in this report.

SLUICE HEAD

The "sluice head" is a term used by many placer miners to express volume of water that is necessary for separating the gold from the gravel in a sluice box. It is an indefinite and unsatisfactory term, as the rate of flow necessary varies mainly with the size of the sluice boxes, the grade at which they are placed, and the character of the gravel. In Alaska a sluice head is usually considered equivalent to the amount of water necessary to carry properly all the gravel that six to eight men can shovel into a 12-inch sluice box set with a grade of 6 inches in 12 feet. According to differences in conditions, a sluice head ranges from 0.75 to 2.5 second-feet, or 30 to 100 miner's inches. The sluice head as used in New Zealand is equivalent to 1 cubic foot per second, or 40 California miner's inches.

DETERMINATION OF FLOW IN OPEN CHANNELS

There are three methods of determining the flow of water in open channels—(1) by measurement of slope and cross section and use of formulas, (2) by means of a weir, and (3) by measurements of the

[19] Bowie, A. J., jr., A Practical Treatise on Hydraulic Mining. 1885, p. 126.

velocity of the current and of the area of the cross section. The method chosen depends on local conditions, the degree of accuracy desired, the funds available, and the length of time that the record is to be continued. A simple method of ascertaining the approximate amount of water flowing in an open channel is as follows:

Select along the ditch, flume, or stream where the water runs smoothly a straight course of nearly uniform cross section. Measure off 110 feet along the channel and set stakes at each end, or stretch a line across, and call the distance 100 feet. Place in the canal as quietly as possible floats made by weighting empty shotgun shells with shot or small gravel and fitting into them cylindrical wooden plugs 4 to 6 inches long. Different kinds of floats may be used, but those so shaped and so weighted as to be least affected by wind are the best. Note the average time in which several floats traverse the distance, divide this distance in feet (100 feet) by the average time in seconds, and the result will be the velocity in feet per second; multiply this by the area of the cross section of the stream in square feet to find the number of cubic feet of water flowing per second. If the cross section of the channel is not uniform, an average should be determined from measurements of the cross section at different places. In surface-float measurements of ordinary streams with rough bottom a deduction of 10 per cent from the surface velocity at the center of the stream is generally made in determining the mean velocity, whereas for canals, ditches, and flumes 5 to 8 per cent may be a fair deduction according to the smoothness of their walls and the form of the cross section.

ALASKA WATER CONDUITS

The accompanying table on water conduits contains important data on ditches delivering water under various conditions. As there are so many ditches, and reliable detailed data on most of them can not be had, only a few selected examples are given. Many of the ditches can now carry only a small proportion of the water for which they were constructed, and as the quantity usually fluctuates greatly during the season the average stated is only approximate. The cross section also is variable. The data given have been obtained from many sources, mainly from operators. To make and to check such measurements was not practical. Alaska miners seldom note the volume of water used. Although the amount of water supplied by some ditches may seem small, it must be remembered that "ground-sluice" or "bank-head" water may be taken from the immediate creek and not drawn from the ditch. The head or pressure is the difference in elevation between the water level in the penstock and the point where the water is discharged, and as work proceeds upstream the head diminishes accordingly.

Alaska water conduits

Locality or ditch	Length, miles	Width, feet		Grade, feet per mile	Head, feet	Average water carried, miner's inches	Cost of construction	Average cost of annual maintenance	Remarks
		Top	Bottom						
Seward Peninsula:									
Miocene ditch	[a] 40	12–16	----	3.37–6.34	320	3,500	--------	$20,000	See p. 53.
Osborne Creek	8	-----	10	5.28	175	700	$39,000	600	
Penny River	6	12–20	----	3.17	90	------	--------	------------	
Big Hurrah Creek	8	-----	8–10	3.3	190	700	40,000	------------	
Fairhaven ditch	[b] 36	11	----	4.22	530	1,200	[c] 650,000	Very high.	Lower part only used (see p. 54).
Candle ditch	[d] 24.5	-----	7	3.7	200	400	--------	8,000	Includes 2½ miles of siphon.
Canyon Creek-Ophir Creek.	[e] 17	10	8	3.17–4.2	220	1,500	175,000	5,000	
Circle-Eagle-Fortymile:									
Mammoth Creek	10.3	-----	7	5–5.3	----	------	--------	Very high.	Upper ditch 3.8 miles, lower 6.5 miles; now in disuse.
Mastodon Creek	1	7	4	6.6	100	350	2,500	------------	
Fourth of July Creek.	10.75	6	4	5.3	160	500	20,000	------------	Cost includes 2 years' maintenance, upper ditch 8¼ miles long, 100,000 square feet reservoir.
Crooked Creek	[f] 8,000	10	6	8	100	500	4,500	Very little.	1,000-foot flume included.
Dome Creek	8	9	----	5.3	170	([g])	35,000	1,500	No flumes; built partly by hand.
Fairbanks:									
Chatanika Creek	6	-----	4	--------	----	500	--------	200	
Pedro Creek	1.5	3	2	4.6	----	75	--------	------------	
Do	[f] 3,000	6	4	4.6	120	200	1,000	Low.	Main ditch, hand dug.
Do	2	8	4.5	6.6	130	300	10,500	700	Cost high, rebuilt; sand troubles.
Hot Springs-Rampart:									
Hunter Creek	[f] 4,000	9	6	9.1	185	500	1,000	500	600-foot flume.
Pioneer Creek	4	6	4	4.6	75	250	6,500	Low.	
Eureka Creek	[f] 3,500	6	4	5.0	70	200	1,000	------------	
Kantishna: Moose Creek.	2.25	10	6	10	250	1,500	10,000	------------	Exclusive of 268-foot siphon.
Ruby:[h]									
Greenstone Creek	2	4	3	9.1	----	100	3,000	350	Hand dug.
Solomon Creek	1.5	4	2	3	----	85	2,000	------------	Do.
Poorman Creek	.75	3	----	--------	----	60	450	------------	Do.
Spruce Creek	.75	4	2	4.4	----	85	600	------------	Do.
Cook Inlet:									
Canyon Creek	1.25	9	5	17.6	350	3,000	--------	------------	
Do	2	5	3	17.6	----	1,000	7,000	------------	
Crow Creek	1.25	6	4	15.8	160	1,200	--------	250	Small reservoir along ditch.
Yentna:									
Peters Creek	2.50	6	4	9.1	180	400	3,500	Low.	
Falls Creek	[f] 1,600	6	4	--------	100	250	1,600	Low.	
Cache Creek	1	12	6	7.9	80	2,200	--------	Low.	For hydroelectric power.
Iditarod-Kuskokwim:									
Flat Creek	[f] 6,000	6	4	4.6	140	350	--------	------------	
Willow Creek	[f] 2,750	5	3	3.7	50	200	--------	High.	Sand troubles.
Otter Creek	4	8	6	3.54	75	300	--------	------------	Used for water thawing.
Moore Creek	[f] 2,800	7	5	5	100	250	800	------------	
Victor Gulch	1.5	7	5	5.5	----	250	6,000	------------	
Candle Creek	[f] 6,000	8	6	6.6	100	300	6,000	------------	Sod lined; muck and soil.

[a] Dexter Creek branch not in use.
[b] Only lower 22 miles in use at 375-foot head.
[c] Subsequent repairs almost doubled this cost.
[d] Total length formerly 34 miles.
[e] Other portions abandoned.
[f] Feet.
[g] Very variable.
[h] Ditches supply drift operations, water not under pressure.

DAMS AND RESERVOIRS

Water is impounded in reservoirs or directly diverted from streams by dams and then conducted to the workings through ditches, flumes, pipes, or hose.

DAMS

Small dams are effectively built with sod or moss (fig. 4). In most places they become permanently frozen, hence will stand at a steep angle, especially if brush and sod are laid alternately. In laying the brush the butts are pointed downstream. Where sod was not available, sacks filled with gravel and sand have been used.

Heavier dams are often constructed by placing one or more logs across the stream and on the upstream side driving spiles which

FIGURE 4.—Typical small dam, made of brush, gravel, and sod, for diverting water to ditch

point upstream at an angle of 50 to 65°. The spiling is then covered with gunny sacking or lined with sod to prevent leakage.

In the larger, swifter creeks strong dams are necessary. These are ordinarily built of timbers up to 12 inches in diameter, notched and placed to form square cribs. These cribs are filled with clay and gravel by hand or by hydraulic means. All dams must be provided with gates and spillways large enough to handle the excess water. The dam shown in Figure 5 is typical.

The timber dam with hydraulic filling under construction on Canyon Creek in the Sunrise district (fig. 1, *50*) will, when completed, be the largest dam to be used for placer mining in Alaska. This dam is in a narrow rock canyon and will serve both for storage and diversion. The base will be 45 feet long and 125 feet thick and the top 125 feet long and 40 feet thick. The total height will be 110 feet, or 92 feet to the bottom of the main spillway, which will be 24 feet wide and in the solid rock wall at one side. There are two 12 by 12 foot outlets at the base, which will be permanently closed when the dam is completed. White hemlock timbers 9 to 16 inches in diameter are used; a network of cribs, 10 feet square, the sides of which are set at an angle of 45° with the stream, is built up and braced with cross timbers and keyed to the rock walls. As construction advances the spaces between timbers are filled with clayey gravel.

RESERVOIRS

In the mountains and in the interior, where the water supply is intermittent, active mining is generally restricted to two or three

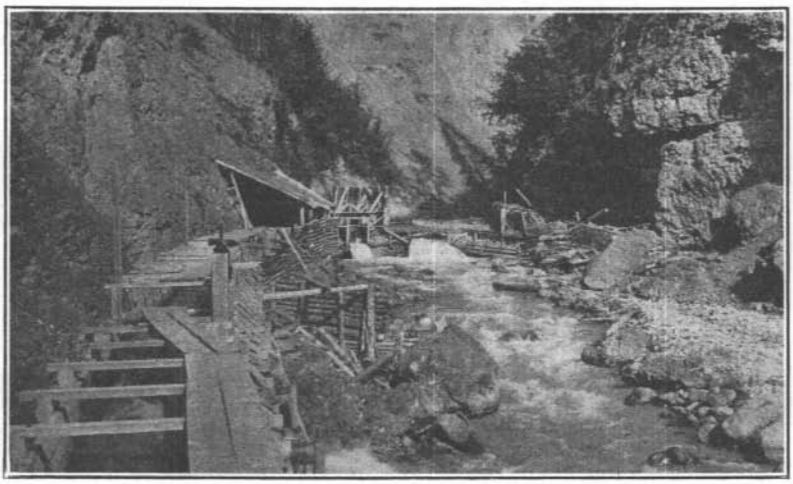

FIGURE 5.—Dam and flume on Dan Creek, Nizina district

months in summer and then is on a small scale. In many places an intermittent supply is caught by constructing banks on the hillsides or damming the natural drainage channels or ditch line. Such reservoirs are rarely more than a few acres in area and a few feet deep and are equipped with hand or automatically controlled gates. There are only a few places where lakes can be utilized for storage or where large storage sites would be practical.

Where various mines use the water repeatedly, settling ponds must be constructed. On Willow Creek in the Iditarod (fig. 1, *21*) large quantities of sand from other mines are brought down the creek. To settle the sand a large dam of moss, brush, and sand has been built, which is made higher as the sand accumulates. It is now 500 feet long, 12 feet wide, and 15 feet high. The cost for construction and maintenance during its life of six years has been about $20,000.

The water from the settling pond is used by two placer mines. During most of the average season the supply is so small that each operator takes water on alternate 12-hour shifts (fig. 6).

SNOW FENCES

The meager water supply of most mines situated on high, windswept places, as high-bench placers, where little snow accumulates, can be much improved by the use of snow fences.

Snow fences similar to those built along railroads were used with satisfactory results on the Upgrade Association property in the Iditarod district. Six-inch boards spaced 6 inches apart are nailed to 2 by 4 inch uprights. Each section is 12 feet long and 5 feet high and is set at an angle of about 60°. Two parallel fences, each 1 mile long, were placed near the summit of the mountain at right

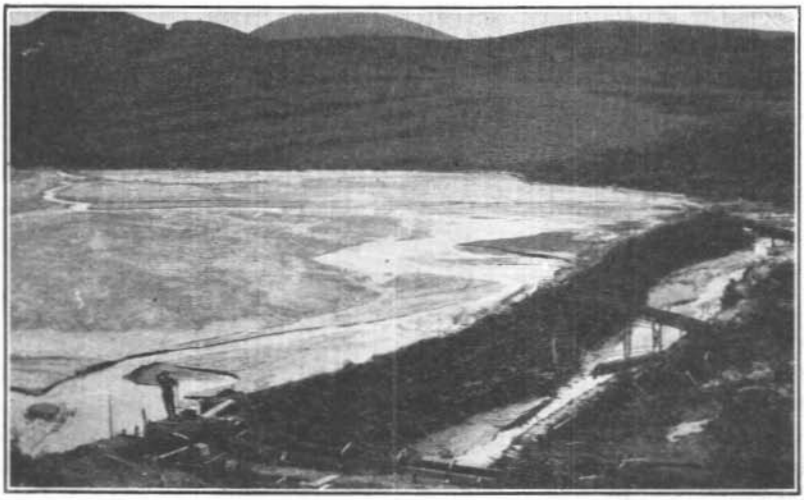

FIGURE 6.—Settling pond for tailing, Iditarod district

angle to the prevailing wind. As the snowdrifts built up, the fences were repeatedly dug out and placed on top until 40 to 50 feet of snow had accumulated. The labor cost was about $1,500. This work lengthened the average water season by five weeks, or until August 1. Snow of such depths soon hardens with the early thaws and prevents the otherwise rapid spring run-off. In the Nome and in other districts brush fences have been successfully used for piling deep drifts.

DITCHES

METHODS OF CONSTRUCTION AND CONDITIONS ENCOUNTERED

Thousands of miles of ditches were dug during the earlier days when richer gravels were being mined. Many of these ditches have been abandoned, and only parts of others are now in use; however, many are now legacies for later miners and enable ground to be mined which would otherwise remain idle. Comparatively few ditches, mostly short ones of small capacity and these mainly in the interior districts, have been constructed in recent years. No new methods of construction have been used, although through past experience and the use of steam shovels, tractors, modern plows, and graders large ditches such as the Miocene, Fairhaven, and Candle on Seward Peninsula could now be dug at lower cost, and many of the difficulties that were encountered could be avoided.

DITCHES ON SEWARD PENINSULA

Seward Peninsula has led in the construction of large, long ditches; had dredging reached the stage of development that it now holds many of them would probably never have been dug. In the interior the ground is in some respects more favorable for ditching than on Seward Peninsula, but conditions are generally adverse for obtaining large volumes of water under pressure, so that no ditches of great capacity or length have been constructed there. In southern Alaska longer ditches than 3 or 4 miles are seldom necessary. The ground there is usually free of frost, and no unusual difficulties in construction are met.

Frozen ground and ice.—The greatest obstacles to ditching in the Seward Peninsula and in the interior are frozen ground and ice, both on the slopes and in the creek valleys. This is especially true where the ground is frozen muck, or where irregular bodies or seams of ice, called "glacier" ground, are present. These ice seams range from a few inches to 3 or more feet thick and from 25 to 150 feet in maximum dimension; their shape is generally oblong, and they are believed to be due to the freezing of seepage water. Most ditches encounter muck; "glacier" ground while common is irregularly distributed. In mucky, icy ground, special methods of construction and precautions must be employed to control the thawing of the frozen muck. A low grade and a slow current are very important when ground is of this character. Muck thaws rapidly on exposure to air and water, and when once beyond control causes much ditch trouble.

Description of ditch construction.—Henshaw and Parker [20] say that over 400 miles of ditch with a capacity of 20 second-feet or greater have been built on the Seward Peninsula. Frozen ground has caused serious difficulties there as well as in the Yukon-Tanana region. The methods of construction and means of overcoming difficulties are described by Henshaw and Parker, as follows:

Ditches are constructed by several different methods, according to the conditions of the ground encountered. Horses have been used for the work wher-

[20] Henshaw, F. F., and Parker, G. L., Surface Water Supply of Seward Peninsula, Alaska: U. S. Geol. Survey Water-Supply Paper 314, 1913, pp. 258–260.

ever possible. In one method the ground is first prepared by removing the moss and turf from a strip 40 or 50 feet wide on either side of the ditch. This should be done, if possible, the summer before actual construction is begun, in order that the ground may thaw more readily. Actual construction begins with plowing, after which some of the material is moved with a grader from the upper side of the ditch to the lower bank until a practically flat bench is produced. The cut is then excavated with horse scrapers down to grade and the material piled up on the lower bank. The ditch is finished by hand, and both bottom and bank are trimmed to an even grade and alignment. The method above described is practicable where the ground contains only small or medium sized rocks and is about the cheapest and most rapid that can be used, but it requires exceptionally favorable conditions to make it a success. Where the ground is naturally unfrozen or can be made to thaw easily, and where other conditions are similar to those encountered in a temperate climate, no difficulty is experienced.

Wherever the ground is frozen muck, or so-called "glacier," it melts rather slowly when exposed to the air, and the work of excavation must be done by hand while it thaws. The best practice is to keep exposed as large an area as possible and to remove the soil in thin layers.

More or less rockwork has to be done on all the ditches. Some of them have had to pass around cliffs of practically solid rock where the construction required a large amount of blasting. Rock cuts offer no problems not met in other fields, except in the method of making the ditch tight, which is done by the use of a peculiar tough and tenacious sod abundant in many places in the north. The sod is cut with mattocks into pieces 1 to 2 feet square and placed in the ditch, bottom up. Two layers are usually placed in the bottom, breaking joints as well as possible, and the whole is carefully and solidly tamped into place. The sides of the ditch are made tight with a sod wall, the pieces being laid one above another, bottom up. Where the sod is above the water line part of the time, the grass usually continues to grow and its living roots bind the material more closely and firmly together. The best sod, and the only kind which fully meets the requirements, is that containing grass roots and very little moss, for the moss is less tenacious and decays more rapidly. Grass, however, is not abundant in many places, and it is therefore often necessary to use sod of inferior quality, with correspondingly unsatisfactory results.

Canvas has been used in some places to line ditches but is expensive and is reported to be not wholly satisfactory. If it is disturbed after it is once laid down it is likely to be torn, in which event it becomes practically useless.

In ground composed largely of frozen muck or ground ice, special methods and precautions must be taken. This material when it thaws leaves a soft residue, largely mud and decomposed vegetable matter, which may be only 20 to 30 per cent of the original volume. Water flowing across such material causes it to thaw rapidly, and consequently when a ditch is built through it precautions must be taken to prevent too much thawing. Where the muck is present the portion nearest the surface usually contains much more earthy matter than that just below, and in many places there is a layer of blue clay just beneath the moss. The vegetable matter close to the surface is also less completely decayed and therefore more solid and tenacious than that lower down.

If this surface covering is allowed to remain in place and the ditch built over it by building up the lower bank with sod and with material stripped from the top, good results can usually be obtained. When stripping is carried to just about the right depth, the water, after being turned into the ditch, will cause the ground to thaw a little. The bottom will settle a few inches, and then the ditch practically builds itself, so that eventually the water is carried in a section entirely below the surface of the ground, and the ditch can not leak because its sides are all soft, fine material, mostly muck and clay, backed by solid and impervious frozen ground. These ideal conditions are generally aimed at by ditch builders but are attained only at certain localities and by special care in building and watchfulness in maintaining the ditch.

EXPOSURE AND GRADE

Experience has proved that wherever possible ditches should be run along southern slopes, as these thaw more quickly in the spring, afford an earlier water supply, have more earth and less rock, and are less liable to contain permanent frost than the northern slopes. Water conducted along southern slopes will also be appreciably warmer, a feature of importance if it is used for thawing frozen ground.

In ground free of permanent frost standard methods of construction with standard ditch constants will produce satisfactory results. The tendency in unfrozen ground is to make deeper, narrower ditches and use higher grades, with consequent reduction in the amount of excavating and the cost of construction. The grade used on the ditch, however, decreases just so much the elevation that would otherwise be available for pressure.

Ditches constructed through frozen muck should be comparatively wide and shallow, with a low velocity, not more than 2 feet per second. In frozen soil, gravel, or clayey slide material, grades up to 9 feet per mile have been used without giving trouble. Under average conditions the Alaska ditches have bottom widths two to three times the depth, top widths to one and one-third to one and one-half times the bottom widths, and side slopes of 45° to as much as 65°. Such high slopes for the sides, however, quickly cut down.

MAINTENANCE AND REPAIR OF DITCHES

Ditches are only used during the open mining season—four to six months—so much work must usually be done each spring in opening the ditch line and in making repairs. Deep snowdrifts often cover parts of the ditch and, before the water can be turned in, a channel must be dug along the bottom. Where the snowdrifts are usually deep, as on the Seward Peninsula, holes are sunk to the ditch bottom at about 100-foot intervals, and these are connected by small tunnels, which quickly enlarge when the water is turned in. Great care must be taken in turning water into a ditch in spring, otherwise the frost will be drawn too quickly and breaks may result. Where there is much slush it should be run off through the waste gates, which should be placed at least every third of a mile and should be of ample size. Failure to draw off the slush may result in choking, overflows, and damage to the sides. At the close of the season the ditch should be drained and all waste gates left open. Figure 7 shows a partly melted snow bank that had been 50 feet deep in places and had covered several miles of the Miocene ditch. The picture was taken on July 5, 1922, two days after a serious break in the ditch a short way beyond this place. The break stopped all mining operations for four days and required the work of 40 men and 3 teams of horses to repair it.

Different means have been tried to keep water running in the ditches in the late fall. One method is to raise the level of the water temporarily, permit the surface to freeze, and then lower the water level, leaving an ice cover. However, such measures are seldom

FIGURE 7.—Remaining portion of snow bridge over Miocene ditch, July 5, 1922

practical, for as soon as freezing weather sets in the water supply usually diminishes very rapidly, although during the middle of the day there may be a good flow until the final "freeze-up."

Conditions in Alaska vary widely and losses in conducting water through ditches have been studied at only a few places. The main factor in seepage loss is the character of the country over which the ditch is built. At ditches properly built through frozen ground seepage losses ordinarily are very small, and unless the season is unusually dry both seepage and evaporation losses are usually compensated for by the water that seeps into the ditch or by small side streams which can be turned in. Seepage measurements made by Henshaw and Parker [21] in 1908 at several ditches in the Seward Peninsula showed the leakage of the Fairhaven ditch, which is built

[21] Henshaw, F. F., and Parker, G. L., Work cited, pp. 263–269.

over frozen muck, to be almost negligible; for the others the average loss per mile under varying conditions of supply, size, character of ditch, and climate was about 0.5 second-foot and may be as much as 1 second-foot; and in a few places where the soil or rock is unusually porous or fractured it may be much higher. On the Seward ditch, which cuts 12 miles of limestone country, there was at one time an unusually large loss of water—investigation showed it to be about 70 per cent—by escape through the limestone crevices. Most of the loss was stopped by lining the ditch with sod and by fluming the worst places.

COST OF CONSTRUCTION AND MAINTENANCE OF DITCHES

Maintenance of some ditches is a large item of expense, although no unusual trouble should result if the ditch is properly constructed and well handled at the start. The greatest maintenance cost is usually for the first two years after construction. Short ditches commonly require but occasional attention, whereas ditch tenders must be employed on the longer ones. One man is generally allotted 5 to 8 miles of ditch to keep in good condition.

The cost of ditch construction is determined by local conditions and the methods used, but under average conditions ditches can be dug for 75 cents to $1.25 per cubic yard. Hand-dug ditches in frozen ground, carrying up to 100 miner's inches of water, cost $800 to $1,500 per mile. Ditches with 4 to 5 foot bottoms, carrying 100 to 400 miner's inches, have been constructed under favorable conditions—ground being broken with horse-drawn plows and excavated by hand—for $1,500 to $3,000 per mile. Ditches to carry 700 to 1,500 miner's inches have been constructed for $2,500 to $5,000 per mile. There are many exceptions to the above, and special consideration must be given ditches that require much rockwork and flume construction. The building of large ditches in Alaska is expensive, and unless a ditch is properly constructed its maintenance over a period of years may cost as much as the original construction. As the ditches are in use for actual mining only three to five months of the year and many of them deliver only small amounts of water, the cost per miner's inch or per cubic yard of placer mined is frequently high. On the other hand, many old ditches are now in use which have either been written off or were obtained by present operators for only a small fraction of the original cost. Under such conditions the cost for water may be very low, and in some districts may permit mining that would otherwise be unprofitable. The sale of ditch water is no longer practical, although in a few places the ditch is maintained by several operators and the water is divided by amount or by time of use.

TYPICAL LARGE DITCHES

MIOCENE DITCH

The Miocene ditch system on the Seward Peninsula is the largest and most extensive in Alaska and originally included 31 miles of main ditch and 24 miles of lateral feeders and distributing ditches. Further extensions were at one time under construction but were not completed. This ditch system diverts water from upper Glacier Creek, upper Snake River, Nome River and its tributaries, and the Grand Central River drainage basin for use on claims along Glacier, Dexter, Anvil, and Little Creeks. Construction of the ditch began in 1901 and was active until 1907.

The main ditch runs from Hobson Creek to the tunnel. As far as the "X," where one branch goes to Dexter Creek, this ditch was made 10 feet wide at the bottom, 14 feet at the top, and 3 feet deep, with a grade of 3.37 feet to the mile. Seventeen miles of ditch from the head of Nome River to Hobson Creek were built 8 feet wide at the bottom, 11 feet at the top, and 3 feet deep, with a grade of 4.5 feet to the mile. From the "X" to the tunnel the dimensions were the same as at the upper end of the main ditch, but the grade was 6.5 feet to the mile. There are 5 miles of rockwork along the ditch, including the 1,800-foot tunnel between the Glacier Creek side and Anvil Creek. The main ditch was originally constructed to carry 3,000 miner's inches of water. From 1910 to 1912 it was enlarged to a width of 16 feet with steam shovels, and the rock cuts and tunnels were also widened to increase the capacity to 5,000 miner's inches. The longest siphon—3,100 feet long and 66 inches in diameter—is across Hobson Creek. The largest siphon—82 inches in dameter—is at Flume Camp. Only 40 miles of the ditch system are now in use, as the Dexter Creek branch and several others are no longer maintained. The ditch has not been cleaned since it was widened and now carries 3,000 to 3,500 miner's inches of water, all of which is used under a maximum head of 320 feet at the Little Creek hydraulic elevator and water-thawing operations.

Construction of the original ditch system is said to have cost about $500,000, and the water rights and other incidental expenses cost about the same. Enlarging the ditch cost about $250,000. The cost of maintenance averages about $600 per mile per season, without allowances for the cost of extensive repairs that are sometimes necessary. Ten ditch tenders are employed throughout the season. In 1921, 312,489 twenty-four-hour miner's inches of water were used, and the cost of ditch maintenance alone was about $20,000.

FAIRHAVEN DITCH

The Fairhaven ditch takes its water from Imuruk Lake, where a dam 500 feet long and 5 feet high was built to form a storage reservoir large enough to hold the total inflow at the lake for two years, if necessary. The upper section is 17 miles long and empties into Pinnell River. Six miles below this point of discharge it enters the lower ditch, which is about 19 miles long. The ditch has a grade of 4.2 feet to the mile and was built 11 feet wide at the bottom, but because of difficulties in controlling such ground it has widened to 15 or 20 feet or more in many places. Maintenance has been exceedingly difficult and costly. Although the ditch was constructed to carry 5,000 miner's inches, it has never carried more than about 2,700 miner's inches. Only the lower ditch is now in use. A maximum head of 530 feet can be obtained from the upper penstock, but this head has been found to be too great for practical use, so a lower penstock was built and the head reduced to 330 feet. The cost of the original ditch construction is stated to have been about $650,000, and before the ditch was finally gotten into shape this cost was practically doubled.

OTHER TYPICAL DITCHES

The following examples are characteristic of many ditches of recent construction.

In the Hot Springs district two ditches 4 and 2 miles long, both 4 feet wide at the bottom, were constructed through partly frozen muck and slide material. Horses and plow broke ground and finishing was done by hand for 30 cents per foot. The cost covers the dam and waste gates.

In the Ruby district a typical small hand-dug ditch through frozen muck, 3,600 feet long and 3 feet wide at the bottom, was dug at a cost of $700; another in the same district, 4 feet at bottom, 2 feet deep, and 2½ miles long, for $1,000 per mile.

In the Rampart district a shallow ditch, 4,000 feet long and 6 feet wide at the bottom on a 9-foot per mile grade, was dug entirely by hand for 25 cents a foot. Three-fourths of the ditch was dug through frozen muck, the rest in gravel and slide rock. There is also 600 feet of 3-foot flume set on trestle on a grade of 18 feet per mile. The fluming cost $2,000, and annual maintenance averages about $500. Much trouble was at first experienced along the part of the ditch that is frozen muck.

In the Yentna district a 1½-mile ditch with a 4-foot bottom was constructed with horse and plow and finished by hand at 50 cents per foot. It was dug through clayey gravel and soil, with a short distance through muck, all free of permanent frost.

In the Fairbanks district a 2-mile ditch 4½ feet wide at the bottom and 8 feet at the top, with a carrying capacity of about 1,000 miner's inches, was dug with plow and scraper through clay and soil at the upper end and slide and loose material at the lower end and hand finished for $5,250 per mile, a high charge for this type of ditch.

One man is kept attending to the ditch because tailing from operations above causes much trouble.

On Candle Creek, in the upper Kuskokwim district, a ditch 8 feet wide at the top, 6 feet at the bottom, and 2½ feet deep, with the lower bank sod lined, was constructed for $1 per foot. The average carrying capacity is about 300 miner's inches. The ditch is cut through frozen muck, clay, and soil. Its low maintenance cost proves that sod lining fully repays the added outlay. Sod is cut in 1-foot squares and, starting at the bottom of the lower side of the ditch, one square is placed on top of the other in much the same manner as bricks are laid; the lining, however, conforms to the slope of the side.

A new ditch 1½ miles long has just been completed in the Innoko district. With the exception of about 1,500 feet of frozen muck, all the material ditched was decomposed slate and schist in place or slide rock, free of frost. A large part of the ditch follows the steep hillside, where a cut in the solid formation 1½ feet deep on the lower side was necessary. The ditch is 5 feet wide at the bottom and 7 feet at top, with a grade of 5.5 feet to the mile; it is constructed to carry about 350 miner's inches. The sod was first removed by hand, then plowed and leveled off with a drag scraper with horses, and dug and finished by pick and shovel. Three to five men were employed for two seasons. The total cost of the ditch was $6,000.

PROPOSED DITCH IN FAIRBANKS DISTRICT

A survey has recently been made for an enormous ditch project in the Fairbanks district. The main ditch would be run from the intake on Chatanika River, three-fourths of a mile below the junction of Faith and McManus Creeks, following the north side of the valley, then carried across the Chatanika River under a 550-foot head through a 7,930-foot wooden-stave siphon 4 feet in diameter to Cleary Creek, then past the head of Little Eldorado and Dome Creeks to Vault Creek, then through a 4,000-foot tunnel to Fox, on Goldstream Creek, where the head would be 350 feet. Here one branch would follow up the north side of Goldstream Creek to Golden and the other branch would continue west as far as Ester Creek. This ditch line would be 100 miles long and about 15 feet wide at the bottom; the ditch would be dug with steam shovels, be run on a grade of 2.64 feet to the mile, and have a carrying capacity of about 5,000 miner's inches. To avoid as much frozen ground as possible, the southern exposure of the hills would be followed and the water carried across the deep draws and valleys, through siphons 4 feet in diameter. There would be 44,000 feet of continuous wooden-stave siphon in this main ditch. The siphons would be placed with a fall of 4 feet for each 1,000 feet, and the grade in the 5 by 6 tunnels would be 2½ feet per 1,000 feet. The minimum flow of water expected at the intake is about 1,600 miner's inches. To assure enough water during low-water periods, a lateral ditch was considered which would double the supply, bringing water from Beaver River to the main ditch at Bell Creek, a distance of 40 miles, including the 2 miles of siphon and 1½ miles of tunnel. A recent resurvey of this project, known as the Seventy-nine Mile or Davidson ditch, has been made. Present plans include a 79-mile system, bringing the water as far as Golden. Plans for a lateral ditch from Beaver River have been abandoned.

FLUMES AND SIPHONS

Flumes and sometimes pipes are used for conducting water across ravines or places below the grade line of the ditch, along the face of vertical cliffs, over ground containing shattered or porous material productive of large seepage and absorption losses, or over ground difficult and costly to excavate. Most ditches encounter some of these conditions and ordinarily some flume must be constructed. Many miles of flume have been built in Alaska, but because the cost of construction is generally high and they are difficult to maintain, flumes should be used as little as possible, especially where ditching can be done or where pipe is permissible.

Flumes are less permanent than ditches, for they are subject to exceptional deterioration as the waterway is not in use for the greater part of the year. Sand and gravel in the water cause deep scouring of the lining boards when in use, and during the winter the action of the ice and frost loosens and warps the boards. Snow and rock slides, floods, forest fires, and the weight of the deep snow may all cause damage. Where flumes are constructed over frozen ground special precautions are necessary to protect the ground from thawing; otherwise the foundations may settle, open the joints, loosen the boards, and make the flume break to pieces. Thawed ground expands on freezing, raising the flume and throwing it out of line and grade. On subsequent thawing, the flume will rarely return to its original position and after several of these successive periods will be so out of position as to be useless.

SUCCESSFUL FLUME CONSTRUCTION

Successful flumes have been built over frozen ground where the heavy sod covering is still intact by placing two heavy log stringers side by side on the sod parallel to the proposed flume; on these are placed the sills upon which the flume is constructed. Where there is no sod, the frozen ground is covered with a thick blanket of sod to keep in the frost. A thick covering of clay has also been used, but it is not a permanent protection. Satisfactory foundations have also been made by digging shallow holes, filling them with gravel, and placing on top a wide plank or timber to distribute the load.

A notably successful flume over frozen ground was built on the Miocene ditch.[22]

This flume is 1,100 feet long and has a width of 8 feet and a depth of 28 inches. It was constructed in 1901, and until 1906 or 1907 it retained practically perfect alignment, both horizontal and vertical. No extensive repairs were necessary on it until 1909. In putting in the foundation, trenches were dug 3 or 4 feet in the frozen ground, which was practically all ice. A sill was laid in the bottom of the trench and the uprights fastened to this sill. The excavated material was then replaced in the trenches and allowed to freeze again into its original condition. Sod was carefully placed over the trench, the

FIGURE 8.—Flume in the Rampart district

uprights were then sawed off to grade, and the flume constructed on them. Even with all these precautions, however, at the end of about eight years the flume was in such bad shape that extensive repairs had to be made.

The grade to be given a flume is generally governed by the topography. Although increasing the grade also increases the velocity of the water and thereby permits use of a small flume at less expense, this practice is not the rule in Alaska. Most Alaska flumes are set on the same grade as the ditch or at a slightly increased grade. There are a few places where the flume grade is twice that of the ditch.

The iron fluming which in recent years has been placed on the market has many advantages over the ordinary board flume and should be considered in districts where lumber is expensive and long life with low maintenance is desired. Figure 8 shows a board flume in the Rampart district.

[22] Henshaw, F. F., and Parker, G. L., Work cited, p. 262.

SIPHONS

Appreciable saving in the expense and length of ditch can often be made by carrying the water across a valley or other deep depression through a siphon, as has been done on a number of ditches in the Seward Peninsula and a few of the larger ditches in the interior. Many large siphons have also been built in Yukon Territory. Riveted steel pipe has been used for many Alaska siphons, although wooden-stave pipe has also been used. Two wooden-stave siphons 42 inches in diameter and 1,050 and 800 feet long were built along the Seward ditch across Hobson and Clara Creeks. Two large riveted steel siphons were built on the Miocene ditch.

PIPE LINES, GIANTS, AND NOZZLES

PIPE LINES

Water under pressure is used for hydraulic mining; it is also used in other forms of placer mining for removing overburden, leveling old tailing piles, or thawing. For such uses it goes from the ditch or flume into the pressure box or penstock (see fig. 9), whence it is conducted through pipes to the giants. The practice in penstock construction in Alaska is similar to that followed elsewhere, although local conditions influence the kind, size, and method of installing pipe lines.

Riveted steel pipe.—Riveted steel pipe with slip joints is generally used, as it is cheaper, lighter, and more easily transported than other steel pipe, and can be readily and quickly laid. With average topography experience has proved that slip-joint pipe of proper gauge will stand great pressure. In present practice 10 to 16 United States standard-gauge pipe is used in diameters of 7 to 36 inches. Long pipe lines are not the rule.

An allowance of 3 inches must be made for each length for joining, as the end of one length slips into that of the next. The larger average sizes should not be less than 14 gauge, otherwise they are easily damaged. The larger end of the pipe to be connected is often heated to expand it, generally by wrapping it with burlap dipped in kerosene and igniting the burlap; the smaller end or outlet of the pipe above is entered and then is driven in with a heavy ram by striking a driving plate covering the opposite end of the pipe. As many of the lines are moved rather often, the ends become enlarged and battered from repeated driving, and the joint becomes leaky. Usually the smaller end is wrapped with burlap or canvas soaked in tar before driving, in order to make a tight joint.

Manufacturers nest three to five different diameters of pipe in one bundle, and either fasten the ends together or wedge or seal them with wooden or metal caps held together by a central iron tie-rod.

The latter method is the best, as the caps save the ends from damage. Nesting pipe for shipment makes a large saving in freight, as pipe is generally rated according to measurement, prevents injury to it, and facilitates transportation. Pipe shapes punched for riveting have been shipped knocked down in bales. Riveting on the ground is generally a poor job. Pipes are usually given a double coating of asphaltum before leaving the factory to protect them from rust and to give a smoother surface to the interior.

Little attention is paid to the upkeep of pipe in Alaska. The pipe soon rusts and scales, and when this happens within, the internal friction rapidly increases. Pipe in such condition should be dipped in asphaltum or a similar substance. A preparation commonly used is made of 28 per cent crude asphaltum and 72 per cent coal tar (free from oily substances).

FIGURE 9.—Dam, penstock, and head of pipe line, Nizina district

Spiral-riveted pipe.—Spiral-riveted pipe with slip joints, but more often with steel or cast-iron flanged joints, is also in use, especially on the Seward Peninsula. Spiral-riveted pipe will stand harder usage and higher pressures than the ordinary riveted pipe but costs much more. Flange joints also have advantages, but they are heavy, expensive in first cost, and, as it is best to have them fitted to the pipe at the factory, can not be nested for shipment.

Wooden-stave pipe.—Wooden-stave pipe lines and siphons have been constructed in the Seward Peninsula and to a smaller extent in the interior. The Grand Central pipe line of the Wild Goose Mining & Trading Co. was built of continuous wooden-stave pipe; the intake was 48 inches in diameter and balance of the pipe 42 inches. Wooden-stave pipe should give satisfactory service in Alaska when assembled correctly and laid on proper foundations. Redwood pipe has proved less susceptible to deterioration under Alaska conditions than pipe made of other woods. Wooden pipe does not expand or contract like steel pipe, has a lower internal friction, and under freezing temperatures will carry water much longer. Its first cost is less than that of heavy steel pipe, and in districts where transportation conditions are favorable it is worthy of serious consideration for large pipe lines when long life is desired.

LAYING PIPE LINES

On account of expansion or contraction from temperature changes steel pipe lines are usually laid when the weather has a more or less constant temperature, as early in the spring or at night. Where the line can be laid on a slight curve, contraction will then tend to straighten out the line and expansion will return it to its normal position. When in use and full of water, a pipe line is practically unaffected by outside temperatures. As the average small pipe line is generally taken down and moved each season, it rarely has expansion joints. Long, larger, diameter pipe lines, which are practically installed for the life of the property, should have expansion joints of some kind or contraction may pull them apart. Pipe lines are protected further with sod, moss, or earth, and along steep side slopes they are buried or covered with a timber shed to prevent injury from slides or falling rocks.

Near Nome six men averaged laying in a 11-hour shift, at a cost of about 9 cents per foot, 500 feet of 20-inch slip-joint pipe which had been used elsewhere but was in good condition. It was laid on a gradual slope where virtually no excavation or foundation work was required.

On Chititu Creek in the Nizina district (fig. 1, *47*) the pipe was laid during the night shift and the foundations and excavations were made during the day. Six nights were required for 15 men to lay 6,500 feet of slip-joint pipe 26 to 18 inches in diameter. The entire construction (which consisted of a gravel and clay filled timber crib dam 100 feet wide, 10 feet high, and 12 feet at the base, with a 24-foot spillway, 144 feet of 3-foot flume, an 8 by 12 foot penstock with a sand box, and the pipe line itself) required 534 man-days, at a labor and mess cost of $3,871.50.

At one mine in the interior six men laid 300 to 500 feet of 16 to 32 inch slip-joint pipe or about 1 mile of small-diameter pipe in 10 hours.

Alaska practice is to use many different diameters of pipe in the line. From a bell-mouthed entrance pipe at the penstock, followed by a length or more of large-diameter pipe, the size of the pipe is reduced from 1 to 4 inches at a time. A pipe line of only two or three different diameters is uncommon, largely because of nesting in shipment and the saving in cost as compared with larger pipe or pipe of heavier gauge. By lessening the diameter of the pipe the heavier pressure can generally be handled safely with pipe of a lighter gauge. The small diameters of many pipe lines and the sharp bends commonly made cause much internal friction or loss in head, a matter of importance in Alaska, where the available head is usually low. These results may be justified if other considerations outweigh the resulting loss in head. Most engineers agree that to obtain efficient and economical operation water should flow in the pipe at a velocity of not more than 3 feet per second. Such a restriction can seldom be economically met in Alaska.

Much of the pipe in use has been obtained from former hydraulic plants for a nominal figure. In many instances more suitable pipe could have been obtained if a new outfit had been purchased, but operators are getting along the best they can with what is available.

CANVAS HOSE

Canvas hose is used at small mines in remote districts for ground sluicing (see fig. 10) and hydraulicking under low pressure. In a few places it is used under as much as an 85-foot head. This hose is generally 10 to 14 ounce duck in 6 to 9 inch diameters. Regulation canvas fire hose and nozzles are also used. Canvas hose kinks, chafes, cuts easily when dragged over the rocks, and is difficult to handle. One ingenious operator has tarred his hose inside and out and has suspended it from timber bents. With shallow ground to mine and under low head, canvas hose has the advantage of portability, but is usually more expensive than pipe of similar capacity.

HYDRAULIC GIANTS

The giants, or monitors, and nozzles used in Alaska are of standard makes, chiefly of Seattle and San Francisco manufacture. Double-jointed giants, with or without ball bearings, are used, and under heads of 150 feet or more deflectors are generally employed for handling them. Deflectors handle giants with ease and much more work can be accomplished. Small giants under low heads are pointed by hand. The average hydraulic mine uses Nos. 1 to 3 giants with 2 to 4 inch nozzles. Nozzles 2½ and 3 inches in size are usual in the interior, and 3 to 4½ inches on the Seward Peninsula; in southern Alaska, where larger volumes of water are obtainable, Nos. 4 and 5 giants with 4 to 6 inch nozzles are often used. No. 7 giants with 5 and 6 inch nozzles are used at one mine there, and although they are too heavy for the present work they were part of the old equipment. As far as known the largest nozzle used in Alaska is at Valdez Creek (fig. 1, 42) and is 8 inches in diameter. When water supplies get low operators are obliged to reduce the size of the nozzles used. For undercutting and for cutting frost under average conditions a smaller nozzle has been found the most satisfactory, the 2-inch size being generally used. Grit in the water, especially glacier water, is a common occurrence in Alaska; it quickly cuts out the gaskets in the giants, cuts the nozzle, and destroys the shape of the jet, causing it to spray. Air in the pipes also causes spraying.

PUMPING

At many placer mines water is pumped for sluicing. Where steam equipment is already in use and fuel is not expensive nor the lift great, the cost of pumping small quantities of water has been found to be little, if any, higher than that of ditch construction and maintenance. Pumping water by steam pump or water power for hydraulic mining has been tried but almost invariably found too expensive. Where cheap fuel or cheap water power is available and the water supply is erratic, the possible savings of a pumping system should be studied before large and extensive ditches are built. Where water must be lifted and a large volume can be obtained under a comparatively low head, the newer and more efficient types of hydraulic rams are a cheap and satisfactory means for raising a part of that water to a height many times greater than the initial head.

WASTE DITCHES AND DRAINS

In mining creek deposits, water must be kept out of the working pit and the seepage drained off. For this purpose sod or timber dams are constructed above the area to be mined. These dams are equipped with gates to deliver ground-sluice water to the pit as required and an ample spillway, with by-pass flumes, or ditches to conduct all excess water around the workings. In narrow gulches a large by-pass flume may be the only practicable installation. In the wider valleys the creek is generally diverted to the opposite side of the valley by wing or diversion dams. All by-pass conduits should be made large enough to safeguard the operation from flood conditions.

Open drains leading from the working pit afford drainage under average conditions. They are carried on a grade as steep as conditions will permit. In the Fairbanks and other districts, mainly at the steam-scraper mines, where it is not practical to carry a long open bedrock drain, the pit is drained by steam pumps. The amount of seepage water is usually small, most of the water coming from the thawing of the frozen gravels and rains, so the pumps run intermittently.

FROZEN GROUND

In many placer deposits frozen ground governs to some extent the method of mining and is a factor that affects cost. Were it not for the frozen condition of most of the deep ground, drift mining could be employed only at excessive cost for timbering and pumping. There are two kinds of frost, permanent and seasonal.

No permanently frozen ground is found along the Pacific littoral. In southwestern Alaska, back from the coast, permanent frost is seldom met, except in a few isolated areas of deep ground mantled with moss and thick overburden. East and north of the Alaska Range in the Yukon and Kuskokwim Basins and on the Seward Peninsula, most of the deposits are permanently frozen, especially where covered with moss and muck. The ground may be solidly frozen to bedrock and some places are known where this condition extends to depths of 400 or more feet. The shallower creek deposits up to 10 feet or so deep, especially those which are mostly gravel and have no covering of moss and muck, are usually free of permanent frost. The beds of the larger watercourses are generally unfrozen, although there may be irregular frozen patches, but the ground in the flats adjacent to such streams is in many places solidly frozen. The gravel benches along the valley walls and the deep creek placers often develop, through drainage, thawed areas which may form more or less defined streaks or channels or may be irregular. Such drainage may be natural, or, as on some of the creeks, subsequent mining has created drainage resulting in the thawing of much gravel. It is not uncommon to find thawed gravel overlain by frozen muck or overburden. Although the rule is not infallible, thawed areas are generally found underlying heavy growths of willows, particularly on the Seward Peninsula.

The occurrence and depth of seasonal frost vary with local climate and conditions. In areas underlain by permanently frozen ground and covered with sod or moss the seasonal freezing affects only a few feet of the surface. Under other conditions the frost penetrates 2 to 10 feet or more each winter. This frozen blanket thaws slowly and when mined often breaks off in large slabs which are troublesome to handle and are a handicap to dredging during at least the earlier part of the season.

COMPOSITION OF FROZEN GROUND

The composition and the physical characteristics of muck and frozen gravel vary, but under average conditions muck contains 25 to 40 per cent organic matter, fine silt, and sand, and 60 to 75 per cent ice. The average frozen gravel contains 10 to 20 per cent ice, although some gravel containing a large percentage of voids may contain more ice, and some of the finer or tightly packed gravels may contain less than 5 per cent. In some instances the voids are partly filled with minute crystals of ice; this condition is known as "dry frost."

PROPERTIES OF FROZEN GROUND

The physical properties of frozen muck are described by McCarthy,[23] as follows:

Frozen muck is a frozen substance having the following physical characteristics: Color, gray to black; composed of organic matter, particles of sand and silt, cemented by ice. In hardness it may be likened to a soft sandstone. The temperature of the frozen muck varies between 19 and 24° F., or 8 to 13° below the freezing point. The average physical characteristics are as follows:

Specific gravity	1.392
Specific heat	.192
Weight of 1 cubic foot .... pounds	87
Weight of solids in 1 cubic foot .... do	49.33
Volume of solids in 1 cubic foot .... per cent	31.9

The figures are taken from a number of experiments made in 1912 by engineers in the employ of the Yukon Gold Co.

The weight of the frozen gravel per cubic foot has been found from the average of a number of experiments to be 137.3 pounds, of which 17.4 pounds is ice and 119.9 pounds solid. The temperature varies between 18 and 22° F., averaging 19°. At one place, where it was possible to get a reading 38 feet below the surface, a temperature of 2° F. was recorded. The temperature of the frozen bedrock varies between 8 and 14°, averaging 11½° F.

Payne[24] made an extended study of frozen ground in the Klondike in 1912 for the Yukon Gold Co. From his tests of 46 samples he has drawn the following averages:

Physical properties of frozen materials

	Black sand and muck	Gravel and sand	Bedrock
Specific gravity, frozen	1.401	2.189	2.590
Specific gravity, thawed and dry	2.411	2.691	2.655
Specific heat, frozen	.196	.172	.183
Per cent ice, frozen ground:			
By volume	68.2	29.1	9.6
By weight	44.7	16.0	4.26
Per cent solids, frozen ground:			
By volume	31.8	70.9	90.4
By weight	55.3	84.0	95.74
Per cent voids, frozen	0	1.28	0
Per cent voids, thawed	6.1	3.97	1.65
Pounds ice per cubic foot frozen ground	39.11	22.0	6.96
Pounds solids per cubic foot frozen ground	48.39	115.50	154.94

[23] McCarthy, E. E., "Stripping frozen gravel in the Yukon": Min. Mag. (London), vol. 10, April, 1914, p. 289.

[24] Payne, H. M., "Development and problem of the Yukon": Trans. Canadian Min. Inst., vol. 16, 1913, pp. 228–240.

The results of 27 tests of temperatures by Payne showed the temperature of bedrock to range from 2 to 14° F., with an average of 9° F.; of gravel, from 17 to 22° F., average 19°; black muck, from 17 to 24° F., average 20°; and sandy muck, from 19 to 24° F., average 21°. He states these show that the mean temperature depends solely upon the nature of the material and not on its depth, the depth of frost line or the water level, or the presence or absence of muck overburden.

Gibson [25] states that the temperature of perpetually frozen ground on Seward Peninsula, as far as known, remains nearly constant around 28° F., except close to the surface, where the temperature is affected by the atmospheric heat or cold during the summer or winter months, or in immediate proximity to subterranean water channels or thawed ground.

PRELIMINARY WORK

STRIPPING OVERBURDEN

In Alaska the gold-bearing gravels are usually covered with moss or sod and a barren or low-grade overburden of muck, sand, gravel, or similar material. In permanently frozen ground this foot or two of moss or sod acts as an impervious and insulating blanket to the material underneath. Except where the deposit is drift mined or thawed by artificial means, this blanket must be removed before the overburden will thaw; for a similar reason this overburden must be removed to expose the underlying gravels. If this material is removed a season or two in advance of actual mining, the frozen gravels will, under certain favorable conditions, thaw naturally.

Where an appreciable depth of barren or very low-grade overburden exists, it is generally customary and good practice first to remove as much of it as is consistent with the conditions and the available facilities before actual mining and sluicing of the gravels are started, not for the possible purpose of thawing alone, but because this overburden can generally be handled thus more cheaply than by putting it through the sluice boxes; such action may also be necessary in connection with the tailing disposal, or in keeping such material as clay and roots from passing through the sluice boxes.

Many Alaska placers are of too low grade to be mined at a profit unless this overburden can first be removed at comparatively low cost. Stripping reduces the volume of material to be handled later by more expensive methods, and the gold content of the deposit is not disturbed. These important features deserve consideration when a placer deposit is being studied, and the stripping operation

[25] Gibson, A., "Thawing frozen ground for placer mining; steam thawing": Min. and Sci. Press, Jan. 17, 1914, p. 143.

should be considered in preparing the ground for mining, much the same as at porphyry-copper, coal, phosphate, and other deposits in the United States.

LIMITING FACTORS

The removal of overburden from extensive areas is seldom feasible under normal conditions, because the water supply is inadequate during the greater part of the season and the creek gradients are low. The depth of overburden to be removed ranges from a few feet to more than 60 feet. Stripping can not be carried below the creek gradient unless the use of an elevator is practical. The water supply at most placers does not suffice for simultaneous stripping and mining. The area that can be stripped, therefore, often limits the volume of ground that can be mined during the season. Overburden is ordinarily removed during the spring high-water periods or late in the fall after the regular mining has been completed.

HANDLING STRIPPED OVERBURDEN

After the moss or sod blanket has been removed the muck thaws quickly on exposure to the air and the action of water, and when free of heavy material can be readily transported over grades of less than one-half of 1 per cent. As most muck is, however, mixed or interbedded with heavier material, such as sand, gravel, clay, roots, or buried timber, grades of less than 2 per cent generally do not permit economical stripping. The duty of water in stripping naturally depends on many conditions but will range from about 3 to 15 cubic yards per 24-hour miner's inch, although 6 to 8 cubic yards is generally the maximum under average conditions.

When the ground has been mined before and the surface is covered with sand and heavy gravel tailing, stripping becomes more complicated and expensive, requiring water under high pressure and special facilities for handling the material.

Moss or sod is best removed during the summer or fall after it is free of frost and should be disposed of so it can not get into the cuts. It is removed by hand methods, plow and drag or scraper, with steam scrapers, or by water under pressure.

STRIPPING METHODS

One of the most satisfactory methods for stripping overburden and that in most general use at the larger mines is to conduct the creek or ditch water to the highest point, whence it is distributed in a series of cross or longitudinal ditches in the muck, placed 10 to 25 feet apart. The water is then turned into them and quickly thaws and cuts a channel through the muck and carries the material to the main drain and to the creek (see fig. 10). The best results follow if the drain is straightened to procure the maximum grade and if curves which retard the velocity are avoided. Efficiency is increased by using water under pressure to keep the cuts clear of caved material and removing the material as it thaws (see fig. 11). Con-

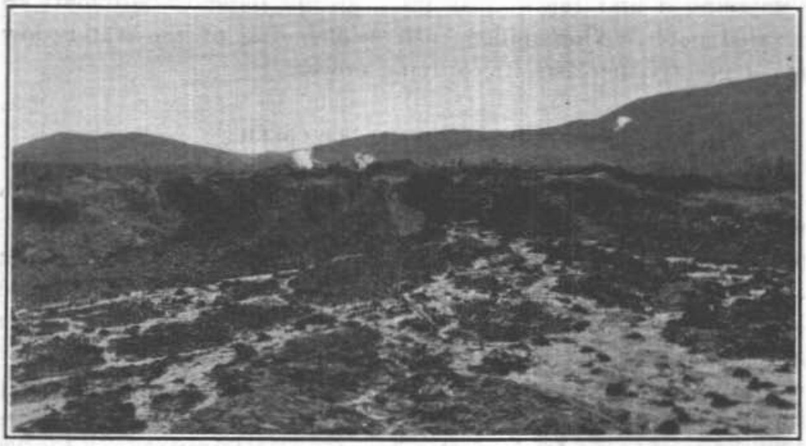

FIGURE 10.—Ground sluicing muck overburden

tinuous application of water under pressure on frozen ground is inefficient practice, for such water performs its principal work in removing material as it is thawed by the air and sun. This work should, therefore, be so planned that nozzling is done at periods best suiting the rate of thawing, which generally ranges from three to

FIGURE 11.—Hydraulic stripping of overburden ahead of dredging

six hours. The frozen ridges or high muck banks are sometimes blasted with slow powder to hasten removal.

At smaller placers, especially where a long narrow area is to be ground sluiced, the entire creek may be turned into a single longitudinal cut; when it has cut as deep and as wide as conditions will permit, the water is diverted by small temporary wing dams and shear boards to undercut and cave the banks. This process is slow, as the frozen banks do not cave readily, and when they do they break off in large chunks often troublesome to handle.

Where the water supply is too small for efficient continuous use it is impounded and released at intervals by hand or automatically operated gates. The sudden rush or booming of the water down the cut greatly increases its carrying power.

STRIPPING ON CANDLE CREEK

One of the largest stripping projects in Alaska is conducted by the Kuskokwim Dredging Co. on Candle Creek (fig. 1, *20*), in the upper Kuskokwim region. The gold-bearing gravels now mined here are covered with 30 to 60 feet of frozen overburden, which must be removed before dredging can proceed. Most of this overburden is yellow and gray muck, of which the lower 6 to 12 feet is tough blue-clay gumbo which is very difficult to disintegrate. Stripping has been kept well in advance, and an area about 400 feet wide and over 2,000 feet long has been stripped to the gravel. The creek gradient is 2 per cent. The sod and moss blanket is cut with sod knives and removed by hand at a cost of 1 cent per square foot. Trenches are plowed at right angles to the main drain and spaced 20 feet apart.

In the early spring, for a period generally of about six weeks when the maximum water supply is available, the water from the main ditch and near-by streams is turned into these trenches. Heavy rains not only increase the water supply but are also of additional help in thawing and washing down the muck faces. The water quickly cuts to the tough clay, which is little affected by it. This clay has to be blasted and then further disintegrated and removed with difficulty by two giants with 3-inch nozzles under 100-foot head. The frozen ridges of muck are removed by the giants. Buried timbers, roots, and old beaver dams, unless removed as soon as possible, clog and dam the cuts and main drain. The limited supply of water permits the use of only one giant during the greater part of the season, yet with a crew of 10 men as much as 300,000 cubic yards of overburden have been stripped during a particularly favorable season. The average cost of stripping is 10 cents per cubic yard.

STRIPPING ON GOLDSTREAM CREEK

On Goldstream Creek in the Fairbanks district (fig. 1, *33*) the sod in many places is removed with a Bagley scraper (fig. 12). The maximum gradient here is about 3 per cent, and water conditions are unfavorable for hydraulicking. Several mines pump the water for stripping, using their steam equipment. At one mine 8 feet, or 24,500 cubic yards, of frozen muck were removed in 70 ten-hour shifts; about 1,800 gallons of pumped water were used per minute through an 11-inch canvas hose with 4-inch nozzle, at a cost of 10 cents per cubic yard. At another placer 7 feet of muck, or 10,000 cubic yards, were removed in 60 ten-hour shifts with pumped water at a cost of 19 cents per cubic yard; powder was used for blasting the muck. A near-by operation used water from a ditch at 80-foot head through two giants with 2-inch nozzles. In 21 ten-hour shifts four men stripped a depth of 5 feet of muck, or 22,000 cubic yards, at a cost of 5 cents per cubic yard.

FIGURE 12.—Bagley scraper operation on Goldstream Creek, Fairbanks district

STRIPPING ON WILLOW CREEK

In the Iditarod district (fig. 1, *21*) on Willow Creek three men in 20 shifts stripped sod from an area of 130,000 square feet with two $2\frac{1}{2}$-inch nozzles under 100-foot head, at a cost of one-half cent per square foot. In the spring, with surface water and water under pressure, a depth of 13 feet of muck, or 67,400 cubic yards, was stripped at a cost of 4 cents per square foot. The cost of stripping the full depth—14 feet—was 9 cents per cubic yard.

STRIPPING ON EAGLE AND MAMMOTH CREEKS

On Eagle Creek in the Circle district (fig. 1, *37*) 6 to 8 feet of soil, sand, and tailing are stripped well ahead of hydraulic mining by piping it to either side of the narrow valley to keep it from passing through the sluice boxes. On Mammoth Creek 2 to 5 feet of moss, muck, and gravel are stripped well ahead of the dredge mainly for thawing purposes. The cost of stripping at these two places is 9 to 15 cents per cubic yard.

STRIPPING IN THE KLONDIKE

In the Klondike, Yukon Territory, where exceptionally abundant water supplies are available and the stream grades are 1 to 2 per cent, extensive stripping has been done. Here the North West Corporation (Ltd.), using 5,600 miner's inches of water, stripped 3,307,670 cubic yards of muck from 1911 to 1914, inclusive, at a cost of 2 to 8 cents per cubic yard.[26] Some large-scale experiments in stripping were also conducted by the Yukon Gold Co., the results of which are commented on by McCarthy,[27] as follows:

> During the seasons of 1906, 1907, and 1909 the Yukon Gold Co. conducted some large-scale experiments with the removal of muck overburden. The tests were conducted at three different points on Bonanza Creek, where every convenience was at hand. Two 5-inch giants under 400-foot head were used at one point, and an additional supply of 3,000 miner's inches was available on Bonanza Creek after it had been used in the hydraulic mines. No trouble was experienced in getting rid of the muck in favorable localities, but the solid matter was deposited a short distance from the operation and had to be driven along. The serious drawbacks were that nothing could be done with the areas that were covered with a tailing of sand and gravel on top of the muck, within the limits of reasonable expense. As the cross ditches cut down to the base level, they lost grade and more and more hand labor had to be employed. Buried roots and stumps had to be cut out by hand at great expense. I have endeavored to show that the stripping alone had its serious difficulties, and that it can not be accomplished with the ease and cheapness to be inferred from recent articles on this subject.

Under average conditions sod and moss when free of frost are stripped at a cost of ½ to 2 cents per square foot. They have been removed by hydraulic methods for as low as ¼ cent, and costs range from that up to 1 cent per square foot. At the larger operations the cost should not exceed ½ cent. By hand methods the cost will range from ½ to as much as 3½ cents per square foot. One man on the average will strip and remove 1,000 to 1,200 square feet of moss per day.

For short periods and under favorable conditions, with a large water supply, frozen muck has been stripped as cheaply as 2 cents per cubic yard, but under average conditions a cost of 5 to 10 cents per cubic yard can be considered reasonable. The average cost of stripping is 10 cents per cubic yard; where conditions are unfavorable or where much gravel is removed, as in some of the ground sluicing, costs of 20 to 35 cents per cubic yard are not rare.

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[26] Department of the Interior, The Yukon Territory. Ottawa, 1916, p. 76.

[27] McCarthy, E. E., "Stripping frozen gravel in the Yukon": Min. Mag. (London), vol. 10, April, 1914, p. 292.

THAWING FROZEN GRAVEL [28]

Frozen gravel and bedrock must be thawed before they can be excavated or sluiced. The thawing is accomplished by the use of hot rocks, wood fires, natural agencies, steam, hot water, or water at natural temperature. The method used depends on the character, depth, and position of the placer, and the resources available.

The methods of thawing in drift mines are described under " Drift mining," so the following statement applies chiefly to thawing from the surface ahead of open-cut mining and dredging. It has been stated that ground may be wholly or partly frozen. In partly frozen deposits there are naturally thawed channels or irregular thawed spots or patches, or one or more horizontal strata may be naturally thawed with frozen beds above or beneath them. At the larger and more systematic dredging projects the areas to be mined are prospected for frost by driving long steel bars from the surface to bedrock or by sinking drill holes. Colored maps are then made to show the outline of the frozen, thawed, and partly thawed areas. The generally irregular occurrence of such areas makes these maps resemble crazy quilts, but they show that the thawed areas are almost invariably connected to a thawed bedrock channel.

HEAT REQUIRED TO THAW FROZEN GRAVELS

The physical characteristics of muck, gravel, and bedrock, and the amount of ice present are most variable, but as an example, to illustrate the amount of heat necessary to thaw 1 cubic yard of frozen gravel, it will be assumed that the frozen gravel weighs 3,500 pounds per cubic yard containing 425 pounds of ice, and the temperature is 20° F. It is desired to heat this gravel from 20 to 36° F., or 4° above the freezing point, to assure complete thawing. The specific heat or the coefficient of thermal capacity for the solids is taken as 0.2, that for ice 0.5, and for water 1.0. The latent heat of fusion of ice is taken at 144 B. t. u. per cubic yard. Then—

		B. t. u.
3,075 pounds of solids raised 16°, from 20 to 36°, 3,075×16×0.2		9, 840
425 pounds of ice raised 12°, from 20 to 32°, 425×12×0.5	2, 550	
425 pounds of ice at 32° raised to water at 32°, 425×144	61, 200	
425 pounds of water raised 4°, from 32 to 36°, 425×4×1.0	1, 700	
Total heat required for the ice		65, 450
Total heat required per cubic yard of gravel		75, 290

This result corresponds very closely to the average British thermal units required at the Yukon Gold Co. operations in the Yukon Territory. The example clearly shows the comparatively small amount

[28] See also Janin, Charles, Recent Progress in the Thawing of Frozen Ground in Placer Mining: Tech. Paper 309, Bureau of Mines, 1922, 34 pp.

of heat required for the solids (13 per cent) and the large amount required (81.3 per cent) to change the ice at 32° to water at 32°.

Taking the fuel value of crude oil at 18,000 B. t. u., bituminous coal at 12,000 B. t. u., and lignite and dry spruce wood at 8,000 B. t. u., and assuming the efficiency of the boiler and distributing plant to be 50 per cent, there will be required to thaw 1 cubic yard of this frozen gravel 8.365 pounds of crude oil, 12.55 pounds of bituminous coal, and 18.82 pounds of lignite or dry spruce wood. When water at natural temperatures is used through points, the calculation involves different conditions. Accurate data are lacking as to the efficiency obtained from water so used and the range of temperature through which the water is most efficient. To continue the example, it will be considered that water after dropping to 36° F. is no longer efficient and, with the initial temperature of the water at 50° F., the range of temperature is 14°; or 1 pound of water between 36 to 50° contains 14 B. t. u. of heat, which at 70 per cent efficiency is reduced to 9.8 B. t. u. Under these conditions 7,684 pounds, or 921 gallons, of this water will be required to thaw 1 cubic yard of frozen gravel.

THAWING WITH HOT ROCKS AND WOOD FIRES

Thawing with hot rocks is no longer practiced. The rocks were heated in a fire at the surface and dropped to the bottom of the shaft or piled against the frozen face in the drifts and covered with sheet-iron or steel plates to concentrate the heat. The heat from the rocks can be controlled more easily than that from wood fires and so obviates much of the sloughing of the sides or roof.

Thawing with wood fires is only a temporary expedient. The use of wood fires at a few very small drift mines in some of the more isolated interior districts is briefly described under "Drift mining." Wood fires are also sometimes used to thaw small areas of river-bar placers which are frozen during the winter, or at a few of the open-cut mines where it may be more practical to thaw some occasional small frozen spot that is troublesome. In thawing from the surface with wood fires an area is stripped of ice or any material that can be removed. Kindling is placed, over which is piled dry wood. Green wood or brush is placed over this and all is covered with sheets of iron or steel to concentrate and conserve the heat. The fire is ignited and burns slowly. During the winter only as much ground is thawed as can be excavated before it freezes again, while during the open season this feature needs no consideration. The size and shape of fires and the rate of thawing vary with the conditions. One fire containing about 1½ cords of wood thawed to a depth of 18 inches, thawing 6 cubic yards of gravel.

THAWING BY NATURAL MEANS OR EXPOSURE TO THE ELEMENTS

The method of thawing with natural agencies, sometimes called "solar thawing," involves utilization of the heat from the air and the sun. The moss or sod blanket must first be removed and any muck or other frozen overburden stripped off according to the methods described under "Stripping overburden."

Where steam-scraper, shoveling-in, and similar open-cut methods of mining are followed and the thawed material is removed from time to time, depths of 6 inches to 1 foot or more may thaw daily. Gravel that is undisturbed and is without drainage is especially slow to thaw and ordinarily thaws only to depths of 2 to 4 feet during the season. Where there is natural drainage along bedrock, or bedrock drains are opened to permit the water from the thawing gravels to seep down into them and flow away, the rate of thawing is greatly increased and the thawing during a season will continue to depths of 8 to 12 feet or even more. Natural thawing has been successfully done in a small way where the gravels were not more than 15 feet deep and where bedrock drainage was established. After the gravels have once been stripped they will again freeze to depths of 2 to 10 feet each winter, which may be to bedrock. As seasonal frost handicaps most open-cut mines and all dredging, particularly during the earlier part of the season, it is usually necessary to thaw some gravel by steam when work begins each year.

Some large dredging companies in the Yukon Territory have stripped on a large scale and then experimented with natural thawing. Even where the gravels, which ranged from 15 to 25 feet in depth, had been stripped several seasons ahead they were found to be incompletely thawed when dredged, and the lower gravels and bedrock were still frozen, except those connected to a thawed bedrock channel.

McCarthy,[29] commenting on experiments by the Yukon Gold Co., states:

> The experiments of the Yukon Gold Co. above described were sufficient to demonstrate to our satisfaction that the method of stripping and so-called actual thawing could not be relied upon for any large-scale operation. The stripping work on claims Nos. 89 and 90 on Bonanza Creek was of no benefit to the dredging operation. Practically all of the ground had to be thawed by steam before the dredges could operate. The ground was stripped and exposed for an average of less than a season before dredging was attempted. On claims Nos. 78 and 79, opposite Trail Gulch, where main ditch water was used for stripping, the ground was approximately 50 per cent thawed when reached by the dredge a season and a half later. On account of incomplete data it is not possible to say positively how much of the thaw was due to stripping and

[29] McCarthy, E. E., "Stripping frozen gravel in the Yukon": Min. Mag. (London), vol. 10, April, 1914, p. 289.

how much of the ground was naturally thawed previously. It is my opinion, from the data available, that the proportion of complete thawing due to stripping was small and altogether disproportionate to the expense of doing the work. The same comments apply to the work on Nos. 62 and 63 Bonanza. In this case the stripping was more thorough and the ground was exposed for an average of over three seasons. The dredge reports show that 50 per cent of the ground was frozen and had to be thawed by steam.

In general, it can be stated that because of the restrictions imposed by Alaska conditions the removal of overburden on a scale extensive enough for dredging on a large scale can seldom be economically accomplished, nor can the removal always be done cheaply enough to justify it as a means of thawing by natural agencies alone. This method, however, holds wider application when its benefits are combined with the object of reducing the deposit to a more practical mining depth.

FIGURE 13.—Driving steam-thawing points ahead of dredge

STEAM THAWING

Until the development of thawing with water at natural temperatures most frozen gravels were thawed with steam applied through thawing points. Steam under pressure of 100 to 150 pounds at the boiler is delivered to the main steam line, whence it is distributed to the various headers or laterals. The main line and headers are wrapped in asbestos packing or other insulating material and incased in wooden boxes packed with sawdust to avoid as much condensation as possible. At intervals of 5 to 6 feet along the headers short steam-hose connections are made to the head of the steam points, or branch lines may be run from the headers to a battery supplying 4 to 10 or more points (see fig. 13). Each header, branch, and connection to the points is equipped with a valve. Boiler plants of 100 to 400 horsepower were required at most single-dredge placers for thawing alone, and one company that ran eight large dredges in the Yukon used 2,000 horsepower.

DESCRIPTION OF STEAM-THAWING OUTFIT

The steam points are made of 6 to 24 foot lengths of ¾ to 1 inch extra-heavy hydraulic pipe. Some sections are 40 feet long and special coupling connections may be used with them. A tool-steel bit is welded to the lower end of the point and has an opening, usually three-sixteenths inch in diameter, through which the steam escapes. A solid standard drop-forged head, which will withstand heavy blows of a hammer, is welded to the upper end.

There are various kinds of steam points, differing in the type of drivehead, steam connection, and form of the bit. The squared or rounded taper point is most generally used, and where bowlders have to be drilled a chisel or a cross bit is provided. With the steam turned on, a point will quickly thaw its way through the muck to the gravel without driving. Where the hole starts in gravel, a steel bar is generally used to make a hole for starting the steam point. Short points or starters 6 to 10 feet long are first used; they are then removed and the longer points driven through the gravel and into bedrock.

As the gravel must thaw ahead before the point can be driven, two men can attend to a number of points. In average gravel the points can be sunk at the rate of about 2 feet per hour. The head of the steam point is pounded with a heavy hammer, and the point is given an occasional twist to aid its sinking into the gravel. In coarse gravel driving the points is difficult. Bowlders must generally be drilled through, or, if the ground is not too deep, it may be more practical to withdraw the point and start a new hole. Anvils which can be attached to the point at a convenient height above the ground for driving are sometimes used, dispensing with high ladders otherwise required and also reducing breakage of the points.

SPACING OF POINTS

The points are spaced 4 to 10 feet apart, the distance being governed mainly by the character and depth of the ground. Usually the ground is thawed 8 to 48 hours, depending on its character and depth, the amount of ice present, and the spacing of the points. After the steam is turned off the ground is "sweated" by the retained heat. The proper spacing, time of thawing, and sweating are most important factors for efficient and economical work. A steam point will thaw its largest area at the top of the hole, so that the thawed part will have a form somewhat similar to an inverted cone; therefore frozen "horses" of gravel and bedrock may still remain between points after thawing ceases. The thawed ground is generally prospected with a steel bar, and should any unthawed areas be located points are driven into them and the thaw completed. Ground 40 feet deep has been steam thawed, but steam thawing of such deep ground for dredging has not been very successful. The thawing of muck by steam is often slow, compared to the thawing of gravel, as the fine thawed material forms a blanket of low conductivity around the point. Clay thaws very slowly, and some clays are baked hard by the steam, making their disintegration in the sluices difficult.

COST OF STEAM THAWING

The cost of steam thawing, in addition to the cost of labor and fuel, is governed principally by (1) the character and depth of the deposit, (2) the amount of ice present, (3) the steam loss due to condensation, (4) the mining method or application, and (5) the scale of operation. The main item of cost is often the driving of the points to bedrock. Steam thawing ahead of dredges has been done for 12 cents per cubic yard, but normally ranges up to 25 cents, sometimes more.

Costs in Yukon Territory.—The Yukon Gold Co.[30] in the Yukon Territory from 1909 to 1914 steam thawed 2,259,487 square yards of frozen ground, or 71.3 per cent of the area worked, averaging 20 to 35 feet in depth, at a cost of \$1.43 to \$1.77 per square yard, an average cost of \$1.57 per square yard. The total cost of steam thawing per cubic yard dredged was 12.18 to 17.62 cents, average 14.53 cents; it averaged 46.5 per cent of the total cost of dredging during this six-year period.

Costs on Otter Creek and Candle Creek.—On Otter Creek in the Iditarod district a 150-horsepower boiler plant handled 95 points, a duty of 1.58 horsepower per point. The deposit was all gravel 14 feet deep. Thawing cost 30 to 45 cents per cubic yard. At a near-by operation a 200-horsepower boiler handled 110 points, a duty of 1.81 horsepower per point. About 100,000 cubic yards of gravel were thawed here one season at a cost of 33 cents per cubic yard. On Candle Creek in the Kuskokwim, where less than 50 per cent of the gravel was frozen, a 100-horsepower boiler plant handled 80 points. The gravel thawed averaged 15 to 18 feet in depth, the muck and other overburden having been removed. The points were spaced at 6-foot centers. Twelve cords of wood, costing \$10 per cord, were burned in 24 hours. With 10 men per shift employed on the thawing operations, about 100,000 cubic yards were thawed in 1922, at a cost of 25 cents per cubic yard. On the basis of 50 per cent of the gravel having to be thawed, this amounts to 12½ cents per cubic yard dredged. Steam thawing ahead of dredges has now given way to cold-water thawing, except where steam is used in a small way at the start of the season, or supplementary to thawing with water at natural temperature.

[30] Perry O. B., "Development of dredging in the Yukon Territory": Trans. Canadian Min. Inst., vol. 18, 1915, pp. 26–44.

THAWING WITH HOT WATER

Hot water instead of steam applied through points has been tried at different times. The results indicated that the ground could be thoroughly thawed, but steam thawing was generally considered to be more effective at that time. Payne [31] made a number of experiments with hot-water thawing in the Yukon. He found that with hot water four times the amount of gravel could be thawed in two-thirds the time with less than half the fuel necessary when steam was used. The points could be driven faster and thawing was more uniform. The great condensation losses that occur with steam and the possibility of back pressure through the points with consequent choking by mud, etc., were overcome. Hot-water thawing has not been adopted, but as it bears a close relationship to thawing with water at natural temperatures its application and merits can be gauged through a study of that method.

THAWING WITH WATER AT NATURAL TEMPERATURES [32]

The value of water as a medium for thawing frozen gravels was recognized some years ago and was probably first applied through thawing points in the experiments conducted on hot-water thawing.

Successful application of the method of thawing frozen ground with water at natural temperatures has made available for dredging many large areas of so-called low-grade ground that have been considered unimportant economically.

MILES METHOD

Two methods of thawing with water at natural temperatures have been developed and are in use. One known as the Pierce method will be discussed later. The method of J. H. Miles [33] has been generally adopted by the dredging companies. The Miles method involves the use of water under pressure, delivered to the ground through thawing points. As the water leaves the points which are driven into bedrock or close to the bottom of a frozen stratum, it thaws and loosens the ground around the point. It is an interesting fact that as thawing proceeds and the cylinder of thawed ground enlarges, the water, instead of returning alongside the point, works its way to the outer edge of the thrawed cylinder, circulating upward along its frozen rim. Experiments by Miles and others show

[31] Payne, H. M., "The development and problem of the Yukon": Trans. Canadian Min. Inst., vol. 16, 1913, p. 237.

[32] See also Janin, Charles, Recent Progress in the Thawing of Frozen Gravel in Placer Mining: Tech. Paper 309, Bureau of Mines, 1922, 39 pp.

[33] United States Patent No. 1339036 was granted Mr. Miles on May 4, 1920. After his death these rights were purchased by the Hammon Consolidated Goldfields Co., operating at Nome. This company has not announced any definite policy concerning the use of the method by others.

that the cylinder thawed by the water in the gravel has its greatest diameter around the outlet of the point, so that thawing is most thorough at bedrock, the place where it is most required. Thawed channels and strata may, however, be encountered or developed, and water seeking the easiest line of flow will follow such courses. Water from one point may then work its way to other points before rising to the surface or may escape by underground channels, leaving intervening spots or "horses" of frozen ground which the water has not been able to reach during the average period of thawing. Such unthawed areas require the placing of additional points.

Distribution and pressure of water.—Water for thawing is delivered under pressure from the ditch or pump or both to the main pipe line, then to one or more branches or manifolds. From these manifolds it is conducted through the various headers or other branches and delivered to the points through hose connections. Each branch and point connection has a valve to control the flow of the water. The size of the pipe lines, headers, and other equipment is governed by the amount of water required. The spacing of the headers and their division is governed by the spacing of the points. The pressure of the water at the points is generally 20 to 80 pounds per square inch and is usually governed by the available head. The loss in friction due to many bends and angles, and the use of small pipe is large. It has been found that in average gravel high pressure is a necessary aid to driving the points, as this will eliminate much of the trouble caused by their plugging; it will more readily force thawed material away from the point and establish better circulation of the water. Miles reported better success in driving with 60 pounds pressure than with 40 pounds. High pressure may, however, cause the points to be forced up the hole and away from bedrock. After the points are once set the pressure is regulated according to what is considered most efficient.

Temperature and source of water supply.—Water at 32° F.—the freezing point—contains no available heat units for thawing, and as most of the water at natural temperatures in Alaska will be near this point, or 4 to 8° above freezing during the spring and fall months, there are practically only three months, June, July, and August, and probably a part of September, when the temperature will be 50° F. or over. During cold seasons the water temperatures may not average over 40°, while during others temperatures of 65 to 70° have been recorded over short periods. The temperature of the water at night may be 6 to 10° lower than during the day. The most efficient and practical results are generally obtained when the temperature of the water on returning to the surface is not below 36 or 38°. Some operators have found this limit to be higher, but in practice it will be governed by the available initial temperature and the water supply. From 8 to 15° of the water temperature is generally all the heat that can be efficiently removed. Wide, flat ditches or shallow reservoirs on south slopes will warm the water supply appreciably. Water supply from ditches may be found inadequate or unreliable for thawing, and the cost of obtaining a ditch supply may be too great to permit economical thawing. Where fuel can be obtained at reasonable cost, pumping may be the most practical means of providing the entire water supply. Pumping is also used to supplement the ditch supply. Where pumping is employed less water would be required, as it could be used again, in which case thawing would be hastened if the water were warmed.

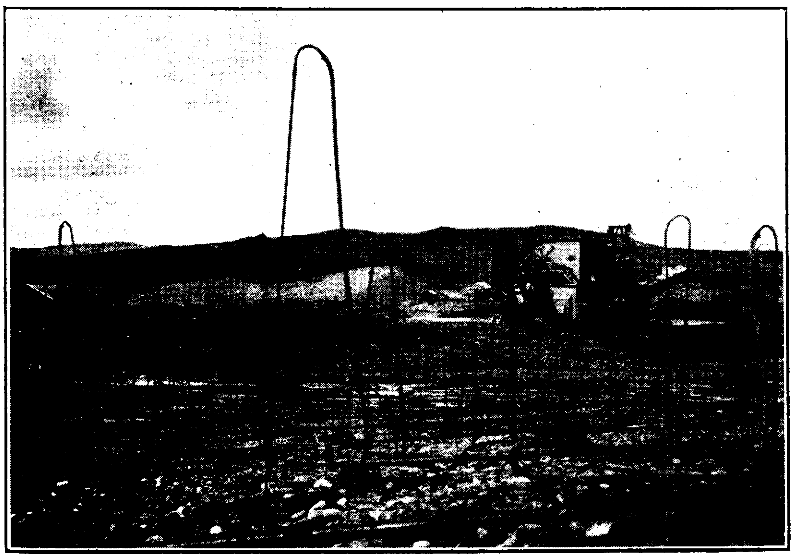

FIGURE 14.—Water thawing ahead of dredges at Nome

Amount of water needed.—The amount of water required depends on many conditions. At Nome, where the ground is being thawed to 60 feet in depth, from 1 to 1¾ miner's inches of ditch water are used per point, under pressures of 30 to 80 pounds. At one operation 1,000 gallons of water were pumped per minute under 17½ pounds of pressure to supply 100 points. The Yukon Gold Co. pumped about 3,500 gallons per minute for 1,000 points.

Driving thawing points.—The thawing points are made of extra-strong pipe ½ to 1 inch in diameter. These may be fitted with the standard steel drivehead; then they are similar to the regulation steam points. Where anvil attachments are used for driving, no drivehead is necessary, the upper end of the point being fitted with a bent pipe or "gooseneck" for water connection (fig. 14). The lower end of the point generally has a steel bit with 3/8 to 1/2 inch opening. In difficult ground a chisel or a cross bit is used for drilling bowlders. In easy-driving, shallow ground a T fitting is used, with a light steel plug at the top for driving and a nipple connection at the side for the water-hose connection. A plain open-end point is often used in ground where driving is comparatively easy. However, this form of point plugs easily. Several different forms of bits have recently been developed with a view to avoiding plugging. One has a pointed tip, tapering to a broad shoulder. The water is discharged through two holes set opposite each other and pointing downward at an angle. Deep flutes from the holes run out to the shoulder. During driving this shoulder deflects the material, keeping the holes clear. On Fairbanks Creek, 1/2-inch water pipe equipped with a head made of a T fitting and similar to the steam sweater is used, and no unusual difficulty is experienced in driving them to bedrock, although heavier points are often required. Thawing points are usually 10 to 20 feet long. Where greater lengths are required, several are joined, special fitted shoulder joints, threads, and sleeves being used.

Water thaws more slowly than steam, and two men can generally look after twice as many water points as steam points. As the ground ahead of a bit must be thawed before the point can be driven, the men work from one point to the other, driving each as far as it will go at that time. Depending on ground and water temperatures, two men can drive 10 to 25 and more points. Under average conditions a point can be driven 3/4 to 1 1/2 feet per hour, and when the water is unusually warm a rate equal to that for driving with steam has been realized. In some light and shallow ground the points can sometimes be set with very little driving, whereas hard driving is generally necessary in deep deposits or heavy gravel. At several operations where heavy driving is necessary a slotted anvil weighing 60 to 80 pounds is keyed on the thawing point at a convenient height. It is fitted with handles inserted on opposite sides for turning the point back and forth while it is being worked down (fig. 15). The head of this anvil is pounded with an 8 or 12 pound hammer. Driving points to bedrock, especially in bowldery gravel, is often slow, and sometimes bedrock can not be reached. There are certain localities on the Third Beach line at Nome where the deposit is 60 feet and more deep and the bedrock is overlain by slabby bowlders. The best method so far developed is to drill holes during the winter with a churn drill and insert the points. The drilling expense is, however, a noteworthy item against low-cost thawing, although the method is cheaper and more practical than driving points in this kind of ground by usual practice. Machine drills with jointed steel were tried but were unsuccessful.

The points are generally set in triangular relation to each other and spaced 8 to 16 feet apart. At Nome, where churn-drill holes are used, they are spaced 32 feet apart, and additional points may be set halfway between them, following ordinary procedure.

The thawing scope of a point when set in equilateral triangular relation is generally considered to be a hexagonal prism, the long radius of which is one-half the distance between points. Thus, with 16-foot spacing there would be four times as much ground thawed per point as when the spacing is 8 feet. Spacing, therefore, has a

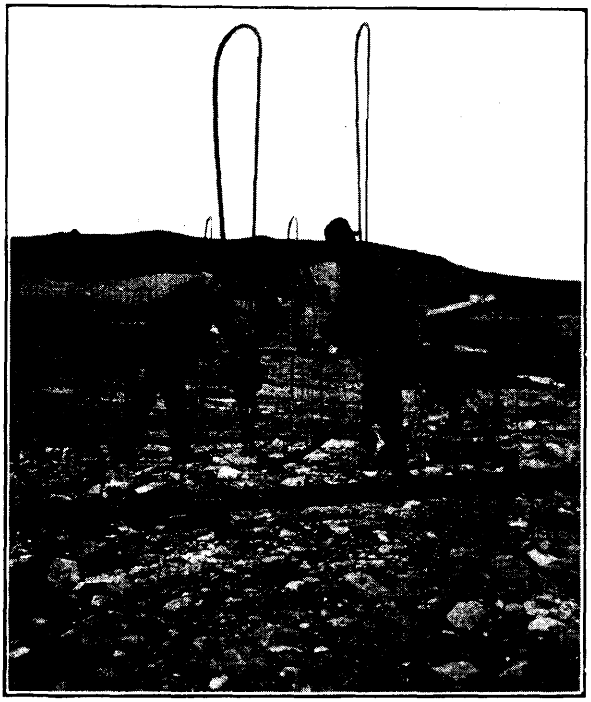

FIGURE 15.—Driving water-thawing points with anvil attachment, at Nome

most important bearing on the cost of thawing, especially where driving the points is difficult.

Time required for thawings.—The time required to complete a thaw is governed mainly by the temperature of the water, the spacing, and the character of the deposit. Although no definite time can be stated, under average conditions thawing has been completed with 8-foot spacing in 4 to 8 days, with 10-foot spacing in 8 to 12 days, and 16-foot spacing in 10 to 14 days. Some thawing of the deep ground at Nome, where the churn-drill holes were spaced 32 feet apart, required 10 to 12 weeks. During a period of maximum water temperature thawing has been completed in about half the time required with average temperatures.

Results of water thawing.—The water boiling up to the surface of the ground makes the ground very soggy underfoot, and as the thaw continues and is completed the ground subsides, the subsidence depending upon the amount of ice that was present and the character of the ground. This point should be considered in estimating the volume of material to be dug by the dredge. In some instances, if much muck overburden is present, the volume is reduced 25 per cent or more by thawing. The subsidence of ground often causes trouble by breaking the pipe lines. The question as to whether ground that has been thawed will freeze again has often been asked. Operators state that permanent frost is gone for good after the ground has once been thoroughly thawed, and that only the seasonal frost returns. If the moss and muck overburden is not removed, this seasonal frost seldom goes deeper than 2 to 5 feet. The shallower gravels which have been stripped of overburden may, however, again freeze to bedrock during the winter. Gravel thawed by water will dig and sluice more readily than that thawed by natural or steam methods, especially when clay is present, as water aids in softening and disintegrating it.

WORK IN IDITAROD DISTRICT

The Riley Investment Co. on Otter Creek in the Iditarod district (fig. 1, *21*), after several years of experimental work, in 1923 installed a 700-point water thawing plant and is successfully thawing ahead of a 3½-cubic foot dredge, which will dig about 1,500 cubic yards, or about 3,000 square feet, of bedrock a day. The creek deposit is medium-size gravel with only a few bowlders. Some clay is present with the gravel, and the slate bedrock is overlain with sticky clay derived from its decomposition. Most of the gravel is covered with 1 to 2 feet of sod, moss, or overburden; there is practically no muck. The average depth of the deposit as dredged is 15 feet. Approximately 50 per cent of the deposit is frozen to bedrock; there are thawed channels and patches, which are first located by driving steel bars to bedrock.

Description of equipment.—Water for thawing is obtained from a 4-mile ditch that follows the north slope of the hill. The flow ranges from 150 to 400 miner's inches. From the penstock to the Y there are 1,800 feet of pipe line 16 to 12 inches in diameter. This line is then divided into two 9-inch branches connecting with the two 9-inch manifolds. Each manifold is 300 feet long and is tapped every 10 feet on both sides with connections opposite each other for 3-inch fittings to which the headers are connected. This connection consists of a nipple, valve, nipple, and union to 40 feet of 3-inch pipe, followed by 40 feet of 2½-inch pipe, then 20 feet of 2-inch pipe, making each header 100 feet long. Usually only every other header connection is used, so they would be spaced every 20 feet along the manifold. Each side of the headers is tapped every 10 feet, but offset to provide a connection every 5 feet and at the end for ¾-inch fittings and a valve, making connections for 21 points on each header (see fig. 16). With this arrangement the thawing points are spaced 10 feet between rows and 10 feet apart along the rows, each row being offset 5 feet so that the holes are placed at the corners of isosceles triangles.

A regulation 16-foot, solid-head, ¾-inch point of the steam type, with square tapered bit with ⅜-inch opening, is driven in stages to bedrock while water is turned on under full pressure. The point is

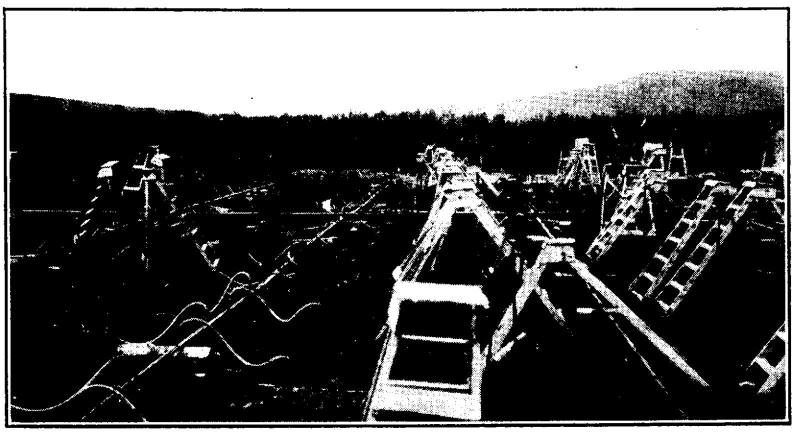

FIGURE 16.—Thawing with water on Otter Creek, Iditarod district

then removed and a "sweater" inserted. In certain areas the sweater can be driven to bedrock without this preliminary procedure. These sweaters are 16 feet long, made of ½-inch extra-strong pipe, and used with the full opening at the bottom. The lower 4 or 5 inches are casehardened. The head is fitted with a ¾-inch **T** to which is fitted 1-inch four-ply water hose. These sweaters are not driven hard, so a ¾-inch plug at the top suffices for a drivehead. The equipment contains 100 points and 700 of these sweaters.

Speed of operation and pressure.—Under the present system eight men in two 10-hour shifts will drive to bedrock about 40 points and set the sweaters and have the thawing under way for an area of 4,000 square feet. One man is allotted the driving of 21 points, which has been found to be about the average number for efficient work. The average time required to complete a thaw is 10 to 12 days, although during periods of higher water temperatures a thaw has been completed in four to five days. Pressures taken when the plant was in full operation were as follows: At Y on main pipe line, 32 pounds per square inch; on 9-inch line, upper end, at first header connection, 29 pounds; on 9-inch line, lower end, at last header connection, 24 pounds; at extreme end of headers, 19 to 23 pounds. No pressures were taken at end of points.

Temperature of water.—Temperatures taken of the water at the penstock during the 1923 season, up to July 7, ranged from 36° to 68° F.; the daily averages were 40° to 60°. On July 6 the highest was recorded as 68° and 69° at the headers. The temperature of the water at night is much lower than during the day; differences of 6° to 8° have been recorded between 9 a. m. and 2 p. m. of an average summer day. In 1922 the temperature of the water averaged between 42° and 44°; 50° was the highest recorded. The coldest water used was in 1922, when the average temperature of some water used from another ditch was 36°. Under ordinary conditions in summer the water entering the ground was generally 10° to 12° warmer than that returning. When the temperature of the water was only 42° to 44° on entering, this difference dropped to about 6°, and there were many times at lower temperatures when only 2° could be utilized. According to the manager, H. Donnelly, more heat units are removed from the water at the start than after thawing has been under way awhile. There were no noticeable differences in the results with ½ or ¾ inch points. In the spring steam is used to thaw the surface frost ahead of the dredge to get under way.

Cost of thawing with water in Iditarod district.—The cost of thawing with water at this placer during a long period can not be definitely stated. The following is, however, the average daily labor cost from which a close approximation can be drawn. Wages are on a 10-hour basis and include board at $3 a day.

Average daily labor cost

8 point men, at $9	$72.00
1 day foreman, at $12	12.00
1 night foreman, at $10	10.00
1 ditch man, at $9	9.00
Half time of blacksmith and helper	10.50
Total daily cost	113.50

From June 22 to July 2, 1923, or 10 days, the above crew set 391 points, and 39,100 square feet, 15 feet deep (21,722 cubic yards), were thawed at a labor and repair cost of 3 cents per square foot, or 5¼ cents per cubic yard. Steam-thawing costs were formerly 35 to 45 cents per cubic yard. In view of the preparatory work, delays, and other factors it seems safe to say that 7 cents per cubic yard should cover the operating cost. Approximately $10,000 is invested in the thawing equipment, exclusive of the ditch line, which remains from former work.

COST OF THAWING WITH WATER AT NATURAL TEMPERATURES

The cost of thawing with water at natural temperatures is governed chiefly by the cost of the water and the character of the ground. The latter affects mainly the cost of driving the points and the amount of water required. Therefore, for low thawing costs, an ample and cheap supply of water under pressure must be available and the deposit must permit easy driving of the points. The operating costs depend upon local conditions and the scale of the operation, and normally range from 7 to 15 cents per cubic yard. It was at one time estimated that in the Nome district water thawing on a large scale could be done for 4 cents or less per cubic yard where large water supplies are available under pressure from ditches already constructed. This low cost is still a long way from realization. Using pumped water and having a large amount of power already available, the Yukon Gold Co. thawed with water at natural temperatures at an operating cost of 10 to 14 cents per cubic yard. On Fairbanks Creek thawing was done with an erratic, small water supply from a ditch for 10 to 12 cents per cubic yard. As only part of the ground dredged may require thawing, the cost of thawing per cubic yard dredged may be proportionately less.

PIERCE METHOD

The Pierce method of thawing with water under natural temperatures involves natural or solar thawing, supplemented by the thawing action of water applied to the surface. The lowest point of bedrock within the area to be thawed is first determined by prospecting with a steel bar or by other means. At this place a shaft about 5 feet square is sunk well into bedrock. A series of shafts or a trench may be used. This shaft or trench is tightly timbered to within a few feet of the bottom and is also extended above the surface of the ground to keep out surface water; the purpose is to permit water to enter the shaft or trench only from the bottom. Some coarse gravel is thrown in around the sides and at the bottom to keep the fine material from filling in. Water under natural flow, usually from the creek, is then allowed to run over the area; it must be run to the extreme edges of the block of ground to be thawed, as thawing will not be accomplished beyond the outer limits of such water. The water seeps into the gravel as it thaws and drains to the shaft or trench, whence it is pumped from time to time to establish circulation and drainage. Where natural conditions answer for similar drainage purposes, the shaft and pumping are unnecessary. As the gravel thaws the water level lowers until the thaw is completed to and into bedrock. Where the gravel is covered with muck, thawing points are driven to the gravel and water is applied to the gravel only; the muck presumably is thawed by natural means. Where beds of clay or other impervious material are interstratified with the gravel, similar use of thawing points would be required to thaw them and to deliver the water below such beds.

Operations on Candle Creek.—Pierce writes as follows on thawing conducted by this method on Candle Creek in the Fairhaven district (fig. 1, *6*):[34]

> In our operations last summer we found on August 4 (the day we started to pump from the shaft) that the seasonal thaw had reached to a depth of 3½ feet * * *. On August 6 the frost line had moved downward to contour line *N* (about 1 foot deeper). On August 18 (the day we stopped pumping) the frost line had moved downward through the entire area to be thawed, passing through and thawing a layer of muck, till it had reached and thawed into bedrock. The entire area, 790 feet upstream and 235 feet downstream from the shaft, with an average width of 60 feet (average depth 9 feet), had been completely thawed in a period of 15 days, with an actual pumping time of 80 hours. This ground was dredged during the same summer and no horses of frost were encountered. The ground thawed well and evenly. The cost per cubic yard to thaw this ground was 1.4 cents per yard, not including any overhead or equipment charges.

A 2½-inch rotary pump with a rated discharge of 250 gallons of water per minute driven by a 4-horsepower Cushman gasoline engine was used for pumping.

Operations on Otter Creek.—This method was tried in 1922 on Otter Creek on a block of frozen gravel 40,000 feet square and 15 feet deep. After 37 days the thawing had penetrated 5 to 9 feet. The temperature of the water pumped from the shaft was always 32° F. (Probably not enough was pumped.) As thawing was too slow and time to complete the thaw was not available, the experiment was abandoned. The management thought that the experiment would have been successful had more time been available. The character of the deposit and conditions on Otter Creek have been described.

Operations on Seward Peninsula.—Small blocks of shallow gravels have been successfully thawed by the Pierce method at certain workings on Seward Peninsula. Where conditions favor thawing by this method, costs should be low. These principles, applied where natural or solar thawing is practiced, would surely improve that method of thawing. A combination of the principles of the Pierce and Miles methods seems to be a most feasible way of overcoming some difficulties encountered and perhaps reducing the cost of thawing at some operations where the Miles method alone is used.

[34] Pierce, E. E., "Cold-water thawing of frozen gravels": Min. and Sci. Press, vol. 124, Feb. 4, 1922, pp. 154–156.

MINING METHODS

OPEN-CUT MINING

Open-cut mining as discussed here embraces all forms of placer mining where the entire deposit is worked from the surface down, except hydraulic mining and dredging, which are considered under separate headings. The simplest forms of open-cut mining use manual labor almost entirely and are now restricted to small workings. At the larger mines machinery excavates and transports gravel to the sluices. The overburden may be removed by stripping, often by some form of hydraulicking.

Only a few of the many methods of open-cut mining formerly used in Alaska are now employed. Mining by means of derricks, horse-drawn scrapers, track-and-incline systems, and similar methods has largely been discarded. Cumbersome, immobile excavating machinery, with belt conveyers, bucket elevators, etc., proved impractical and too costly for use under Alaska conditions. Steam-shovel mining generally failed, especially when handicapped with the additional cost of steam thawing the frozen gravels. The steam shovel is an efficient digging machine, and although it can handle heavier material than other mechanical excavators it lacks important features necessary for efficient placer mining. Mechanical excavators for open-cut placer mining should possess mobility, a relatively large digging radius, and the ability to dump their load directly to the sluices. Most intermediate conveying systems can not keep pace with the excavating machine; the additional cost for such equipment plus the cost of operation generally prohibit their use on the lower-grade gravels. Although all mechanical excavators have their limitations, the drag-line and the cableway types fulfill most of the requirements and when employed under suitable conditions can be successfully operated with less labor, power, and maintenance than the bottomless type of steam scraper.

Manual methods, such as beach mining, ground sluicing with shoveling in, and booming with shoveling in, are becoming obsolete in many districts but are still popular with small mines. Such methods require little capital and are often the most practical for mining small areas where the water supply is small or intermittent.

The depth of deposit that can be mined by open-cut methods is governed principally by the depth of overburden that can be removed by stripping. Mechanical excavation in open-cut placer mining is generally limited by Alaska conditions to gravels not exceeding 8 or 10 feet in depth. One great advantage of open-cut mining is that it permits natural thawing of shallow exposed gravels after the overburden has been removed.

MANUAL METHODS

BEACH MINING

Sea-beach mining was at its height during the early days following the discovery of gold on the beaches at Nome, Lituya Bay, Yakataga, Kodiak (fig. 1, *1*, *51*, *52*, and *54*), and elsewhere. The richer deposits were soon exhausted by hand methods, and repeated attempts to work beach sands on a larger scale with mechanical equipment failed. This mining is practiced intermittently, usually after a storm when the high surf washes the overburden of beach material, leaving a new concentration of the heavier black or ruby sands containing gold. These concentrates are washed in rockers, long toms, surf washers, or small sluices. On the Nome beach small prospect holes are dug to locate the ruby-sand concentrates, which are usually covered with a foot or more of barren sand and gravel. This

FIGURE 17.—Beach mining with long tom at Nome

overburden is shoveled away, and the 2 to 3 inch depth of concentrate is shoveled into buckets or wheelbarrows and transported to the washing device.

Long toms.—The long tom is a small sluice box with a grizzly or screen at the head for removing the coarser material. For saving fine gold the box is set at a high gradient, 3 to 4 inches to the foot, and the screened material is passed over riffles and amalgam plates. The plates are protected from scouring with ½-inch screen or punched plate. The water for sluicing is usually bailed with a large dipper (see fig. 17).

Surf washers.—The surf washer can only be used when the surf is of proper height. It is somewhat similar to the long tom but wider and shorter. The incoming surf rushes up the sluices, washes material from the hopper, and on retreating carries it over the riffles and plates (see fig. 18). The average duty per man per 10 hours for long tom and rocker work is 3 to 5 cubic yards. One man can attend to two surf washers, and in one instance 8 cubic yards per 10 hours were handled.

GROUND SLUICING

Stripping by ground sluicing has been discussed in a previous chapter. Ground sluicing as a mining method, however, removes much of the gravel, leaving the balance to be mined usually by shoveling in or some similar method and is best adapted to shallow gravels, usually not over 10 feet deep, which contain coarse gold, and to richer gravel deposits overlain with muck or other light material that can be cheaply removed. In order to ground sluice gravel successfully, steeper grades are necessary than for removal of the light overburden. The most favorable conditions for ground sluicing are on the benches and the upper reaches of the creeks. At several bench placers that have exceptionally good dumping facilities and favorable grades but

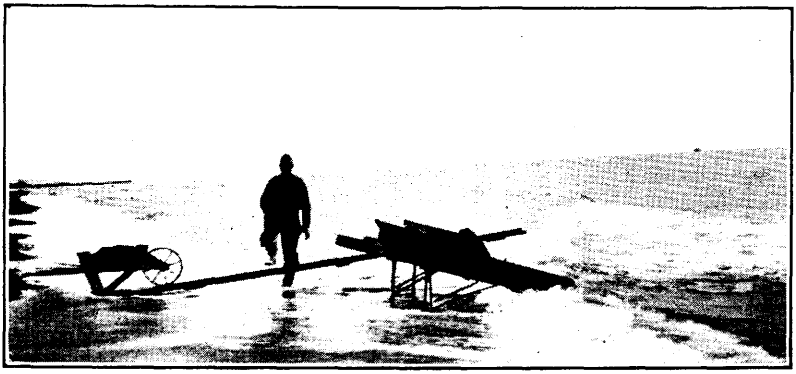

FIGURE 18.—Beach mining with surf washers at Nome

water supplies that are usually small, gravel faces as high as 80 feet are being ground sluiced; and on the creeks numerous deposits ranging from a few feet up to more than 20 feet in depth, half of this being overburden, are successfully handled by ground sluicing.

For sluicing creek deposits a dam with gates and spillways and a flume or ditch for by-passing excess water are constructed across the creek just above the ground to be worked. When ground sluicing is to be followed by shoveling in, the first cut is made along one side of the pay channel, and all the water is confined to this cut, which is 12 to 16 feet wide and 100 to as much as 1,000 feet long. The overburden, and as much gravel as it is practical to remove, are sluiced through this cut, concentrating the gold in the remaining gravel. When bowlders accumulate, they are stacked by hand beside the cut. Where the grade and other condtions permit, and where the bedrock is rough and slabby and so affords a natural riffle, the sluicing may be carried to bedrock. Under average conditions, however, 1 to 4 feet of gravel may remain to be shoveled into the sluice boxes (see fig. 19) or excavated by other means. Usually only one cut is ground sluiced and shoveled-in at a time; this is done by one to four men, and often only one cut is completed in a season.

Ground sluicing is usually done when advantage can be taken of spring floods; the rest of the season is spent in shoveling-in. After the first cut has been completed the water is deflected against the bank by shear boards and wing dams, and another parallel cut is ground sluiced: one dam thus answers for the entire width of the channel. At some mines, particularly those working bench deposits, water from

FIGURE 19.—Shoveling into boxes below automatic dam, Rampart district

a ditch is allowed to run over the banks, washing down material which is then carried onward by an additional supply of water.

BOOMING

In the interior districts the water supply at most placer mines is small during all or the greater part of the season. Then the water is impounded back of the dam or in the ditch, and on being released at intervals by hand-operated or automatic gates rushes or booms down the cut, carrying the material with it. When water is so used for ground sluicing, the operation is known as "booming."

Swinging gates.—Different types of automatic or self-dumping gates are in use, the swinging type being most common. The heavy wooden gate swings outward on a horizontal pivot that is set one-third the height of the gate from the bottom. When the water rises to more than two-thirds the height of the gate, the latter is automatically released by an ingenious device, and when the reservoir is nearly empty the gate returns to its closed position. The heavy jarring, however, may cause the dam and gate to leak. This is partly overcome by making the timbered section of the dam on each side of the gate independent of the main structure, filling these section with clay and cushioning the gate seat with strips of canvas.

Automatic swing gates are usually 4 to 10 feet wide. At some mines one or two small, light gates 2 to 4 feet wide and generally built into the side of the ditch are used. These gates are horizontally pivoted at the bottom and controlled by a counterbalanced weight. Canvas is nailed to the gate and to the sides and bottom of the chute to make it water-tight. This canvas acts like a bellows when the gate opens and closes. When a gate is released, it usually sounds an alarm to warn the men in the pit.

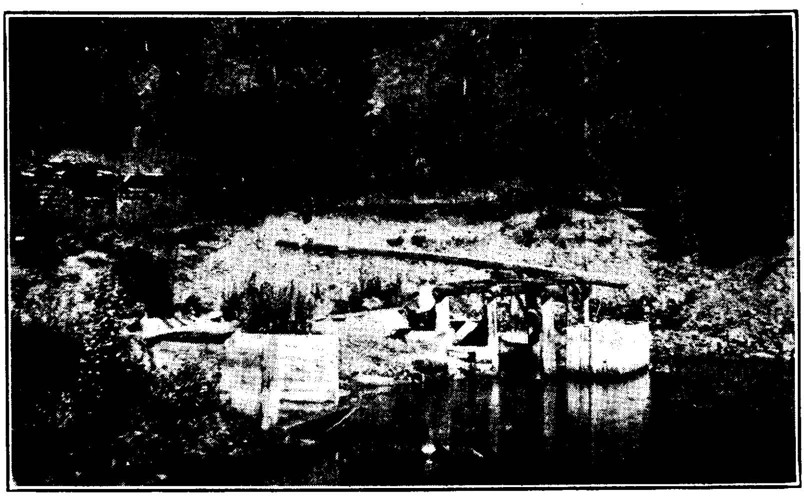

FIGURE 20.—Automatic gate, box type, Rampart district

Box gates.—The box gate, which works vertically in guides and has special releasing devices, is also used. Since the action of the gate is more gradual, there is no undue strain on the dam. As the box rises the water runs out through the bottom and on returning to position the box slips over a cushioned shoulder that forms a tight connection (see fig. 20).

SHOVELING IN

Shoveling in as adapted to rich placer gravel not over 6 or 8 feet deep, but as such deposits are now rare in Alaska it is generally restricted to the shallow gravels remaining after ground sluicing or booming. The method is simple and permits careful cleaning of bedrock. The dam at the head of the pit is necessary in creek deposits to keep out excess water; seepage water is handled by open or by small inclosed drains. For favorable conditions the bedrock grade should be steeper than the required sluice grade, and means should be available for the natural disposal of tailing.

The sluice boxes are usually 12 to 14 inches wide, in telescoping sections, with pole riffles. Where the bedrock grade is not adequate, they are mounted on low trestles or posts and braced to bedrock or the sides of the cut. The usual grade used is 6 inches to the 12-foot box, although more is preferred. A long string of tailing boxes is usually required to provide more dump room. The bottoms are lined with an extra thickness of board or light sheet iron or steel and set at a lower grade than the regular sluice boxes, usually 4½ to 5 inches. Water is conducted through a flume directly from the dam to the head of the boxes or through canvas flume hose or pipe. The width of cut most practical for shoveling directly into the sluice is 6 feet on either side, which has established the practical unit of the "box length" or an area 12 feet wide and the length of one box (12 feet). Only the lighter material is shoveled in; the larger rocks, about 5 inches or over, are piled on cleaned bedrock. From 1 to 3 feet of bedrock may be taken up and if it is hard or creviced much pick work is required.

The duty of shoveling in varies chiefly with the character of the gravel and bedrock, the height of lift, and the shoveler's efficiency. The maximum practicable lift in shoveling gravel is 6 to 8 feet. Where the gravel and bedrock must be picked and many bowlders thrown out, and where bedrock is difficult to clean, the duty becomes low. Under Alaska conditions one man will shovel from 2½ to as much as 10 cubic yards in 10 hours with lifts of 3 to 7 feet, and the depth of material shoveled is usually 1 to 5 feet. An average day's work for a shoveler in the interior districts during the boom days was considered to be 7 to 8 cubic yards.

COSTS OF GROUND SLUICING AND BOOMING

Ground sluicing and booming are very closely allied at most small placers. The cost of ground sluicing and booming is 15 to 35 cents per cubic yard, as a rule, although under the most favorable conditions costs have been as low as 7 cents. Ground sluicing or booming, followed by shoveling in, involves an average expenditure of $350 to $1,500 in equipment, exclusive of ditches. The average dam equipped with an automatic gate costs $250 to $500. Some miners, in estimating their costs, add $1 to $2 per day for each man employed, for depreciation of equipment.

The cost of shoveling in is variable, ranging from $1.25 to as much as $4 per cubic yard. In easily dug gravel, when other conditions are favorable, as at one mine on Seward Peninsula, the cost of shovelng in was $1 per cubic yard. In the Hot Springs district a 50 by 500 foot cut was boomed of frozen muck and a few feet of gravel to a depth of 25 feet at a cost of 7 cents per cubic yard. Shoveling in 2½ feet of gravel and bedrock cost $2.30 per cubic yard. The combined cost was 30 cents per cubic yard.

Costs in Rampart district.—On Little Minook Creek in the Rampart district (fig. 1, *31*) 18 feet of muck and gravel was boomed from a 12 by 600 foot cut at a cost of 18 cents per cubic yard. Two feet of gravel and bedrock, which required much picking and throwing out of half as bowlders, was handled at a cost of $2.20 per cubic yard. The combined cost was 38 cents per cubic yard. This was the fourth cut and cost much less than the first. One mile down the creek a booming operation taking out the first cut 1,000 feet long and 12 feet wide removed 7½ feet of muck and gravel for 22 cents per cubic yard and shoveled in 2 feet of material, 60 per cent being bowlders, at a cost of $2.80. The combined cost was 77 cents per cubic yard.

Costs in Ruby district.—On Greenstone Creek, in the Ruby district (fig. 1, *28*), sod was stripped by hand and the muck and gravel ground sluiced off to a depth of 6 feet in a pit 60 by 200 feet for 38 cents per cubic yard; 2 feet of material were shoveled in for $1.65; the combined cost was 70 cents per cubic yard. On the same creek, but in a bench deposit with steeper grade, a 10-foot depth of muck and gravel was ground sluiced for 26 cents per cubic yard, and 1 foot of material was shoveled in for $2.56. The combined cost was 47 cents per cubic yard. The estimate of $12 per man per eight-hour shift used there is considered as covering depreciation. In other localities combined costs for ground sluicing and shoveling in range from 25 cents to $1 per cubic yard.

SELF-DUMPING CARRIERS

The method of shoveling the gravel into wheelbarrows and wheeling it to a bucket which is hoisted up an inclined cableway and automatically dumps into the sluices is still in use at a few small mines in the interior district. The requisite conditions are similar to those for ground slucing and shoveling in, but by this method the gravel is conveyed from the pit to a place where adequate grade for the sluices and enough dump room can be obtained. The pits worked are not over 150 feet in greatest dimension, as 75 feet is generally the practical limit of wheeling distance to the centrally placed bucket station. The bucket rests in a timber crib, its top level with the bedrock. The shoveler spends one-fourth to one-third of his time wheeling, and to the cost of wheeling must be added the cost of fuel, the hoist man's wages, and the wear and tear on equipment. From this it would seem cheaper to shovel the gravel directly into sluice boxes. However, use of the bucket and carrier permits a wider pit and speeds up the work, particularly for easily shoveled gravel and unfavorable sluicing conditions.

The self-dumping bucket and carrier, steam hoist, and other equipment used in this method are similar to those used at small drift mines. The buckets hold two to five wheelbarrow loads, and the steam hoists are of 5 to 15 horsepower. At three operations noted a high shoveling and wheeling duty of 7 to 9 cubic yards was obtained. The cost exclusive of ground sluicing ranged from $1.75 to $2.50 per cubic yard for handling 2 to 5 foot depths of gravel and bedrock.

Costs of typical operations.—At one property on Ophir Creek in the Innoko district (fig. 1, *22*) 22 feet of cover (18 feet of frozen muck and 4 feet of gravel) were stripped at a cost of 16 cents per cubic yard, then 5 feet of gravel and bedrock were mined by self-dumping carrier for $1.75 per cubic yard. The combined cost for the 27 feet was 42 cents per cubic yard. At an adjoining operation a similar method was being started; there were 35 feet of frozen muck and 6 feet of gravel, and the operators estimated mining would cost 50 cents a cubic yard.

On Chatham Creek in the Fairbanks district (fig. 1, *33*) 10 feet of overburden were ground sluiced at a cost of 16 cents per cubic yard, and 4 feet of gravel and bedrock were handled by bucket carrier for $1.25 per cubic yard. The combined cost for the 14-foot depth was 48 cents per cubic yard.

MECHANICAL METHODS

STEAM SCRAPERS

Until recently steam scrapers were used by a large number of placer operators in the interior districts, but only a comparatively few are now active. Profitable scraper operation is diminishing through depletion of the available areas or is being replaced by less costly methods, mainly dredging. Small drag scrapers and wheel scrapers, which were of light construction and difficult to handle under power, were replaced by heavy scrapers of the bottomless or Bagley type and the slip-toothed type. Bottomless scrapers are more efficient, but slip scrapers are still being used at a few small mines. Both types are also used for stacking tailing at some hydraulic mines where the water supply is inadequate.

Steam scrapers are adapted to mining comparatively large areas of shallow gravel without large bowlders where the bedrock is not hard or irregular and the grade necessitates lifting the gravel for sluicing. The gravel should not be frozen, and the pit should be free of water. For mining thawing ground the Bagley scraper has a decided advantage over other mechanical devices; the scraper can be readily shifted and the material removed in shallow cuts as it thaws naturally. Usually the overburden is removed the season before to let the gravel thaw; even then frozen ground may be found if proper drainage has not been provided. During an average season thawing ordinarily keeps pace with scraping, varying from 4 to 12 inches a day. A season of much frost and slow thawing greatly handicaps the scraper.

With steam scrapers as much overburden as practicable is removed by hydraulicking or other means to reduce the volume of material to be scraped and transported to the sluices. After the overburden and any barren top gravel have been removed by the methods described under "Stripping overburden" there will then remain under average conditions 4 to 8 feet of pay gravel and 2 to 4 feet of bedrock to be put through the sluices. Hard, irregular, or creviced bedrock can not be cleaned properly with the scraper and requires some handwork.

The power plant is installed where two or more pits can be worked; the preparatory work usually is done in fall or early spring. Scraping the pay gravel is ordinarily started after spring frosts are over, or early in June, and continues until the first heavy frosts, about the latter part of September.

The large power consumption, high labor costs, costly set-up, excessive cable wear, and repair charges involved in handling comparatively small amounts of material make steam-scraper methods impractical for mining the present average low-grade Alaska gravels. The use and limitations of the two types of steam scrapers are described in more detail below.

BAGLEY OR BOTTOMLESS TYPE SCRAPERS

The Bagley or bottomless scraper has a curved back and can be used with either side down, the edges of the back being fitted with knives for peeling up the dirt, or with heavy teeth for scraping heavier gravel or bedrock. The heavy haulback lift attached to the back of the scraper adds weight to the cutting edge. This haulback lift stands vertical when the scraper is pulled forward and lies flat when pulled backward, raising the teeth and cutting edge to permit the scraper to be handled more readily. As the scraper is pulled forward it scrapes up its load, the back being slightly lifted, and the whole load is dragged over the top of the ground. The load is dropped by pulling the scraper backwards. The scraper usually delivers a full load and can push considerable loose material ahead of it, making it efficient for "yarding" or stacking material until it can be removed from the pit.

The following table shows the more important details of the Bagley scraper in the sizes used in Alaska. Larger scrapers have been used but have not proved satisfactory. By renewing the plates, teeth, and other parts the scraper has a long life; many have been used five seasons and more.

Details of Bagley scrapers [a]

Size ... feet	3½	4	5
Capacity ... cubic yards	1¼	1¾	2½
Price f. o. b. Seattle:			
With teeth and haulback	$382.50	$446.25	$535.50
Without teeth and haulback	$291.00	$357.00	$427.00
Weights:			
With teeth and haulback ... pounds	3,100	3,270	4,125
Without teeth and haulback ... do	2,130	2,180	2,680
Number of teeth	5	6	7
Engine required (compound-geared)	8 by 10	9¼ by 10	10 by 12
Speed of main line at drum, per minute ... feet	Up to 175	Up to 260	Up to 250
Speed of haulback lines at drum, per minute ... do	Up to 350	Up to 500	Up to 550
Approximate pull on main line at drum ... pounds		31,300	37,400
Size cable recommended for lead ... inches	⅞	1	1⅛
Size cable recommended for haulback ... do	¾	⅞	1

[a] From manufacturer's catalogue, 1923.

Some mines use whatever equipment is available and may therefore have a poorly balanced plant, but as the speed of operation is governed principally by the scraper engine, the engine should be ample for all demands. Compound-geared, three-drum, double-cylinder scraper engines are used. The average pit at the large operations ranges from 275 by 300 feet to 300 by 400 feet, while at the smaller ones the pits may be half this size.

Description of Bagley scraper operation.—A typical arrangement for a Bagley scraper operation is shown in Figure 21. Short masts and deadmen, securely anchored, spaced 50 to 75 feet apart, are installed around the edge of the pit for the sheaves and guide blocks. Two short masts or deadmen are placed one on each side, in front of the main hoist; they serve as anchors for the main lead sheaves. A 50 to 60 foot gin pole to carry the sheave for the car cable is installed back of the sluices in line with the track incline. All sheaves are of manganese steel. The usual diameters of the main lead or head sheaves are 30 to 36 inches and for the haulback sheaves and guide blocks 14 to 18 inches. Cable wear is excessive, due principally to abrasion by the sharp sand. The greatest wear is usually 100 feet or more ahead of the scraper, and about the same distance ahead of the engine, where the cables go over sheaves. Breakage of the individual wires due to sharp bends over the sheaves seldom causes undue damage to the cables. Under steady use a set of cables often lasts only four to six weeks. A high-grade, six-strand, 19-wire steel cable with hemp center is used. By means of two haulback or tail lines, which are guided from the shifted positions of the sheaves, the scraper can be dragged to any desired place in the pit.

On being pulled ahead the scraper takes a long shallow cut in filling itself and is then dragged to the underground loading station, where the teeth engage a timber stop, the load dropping through an opening into the car below. This car, which is self-dumping, is used in different sizes, holding 2½ to 4 cubic yards of loose material.

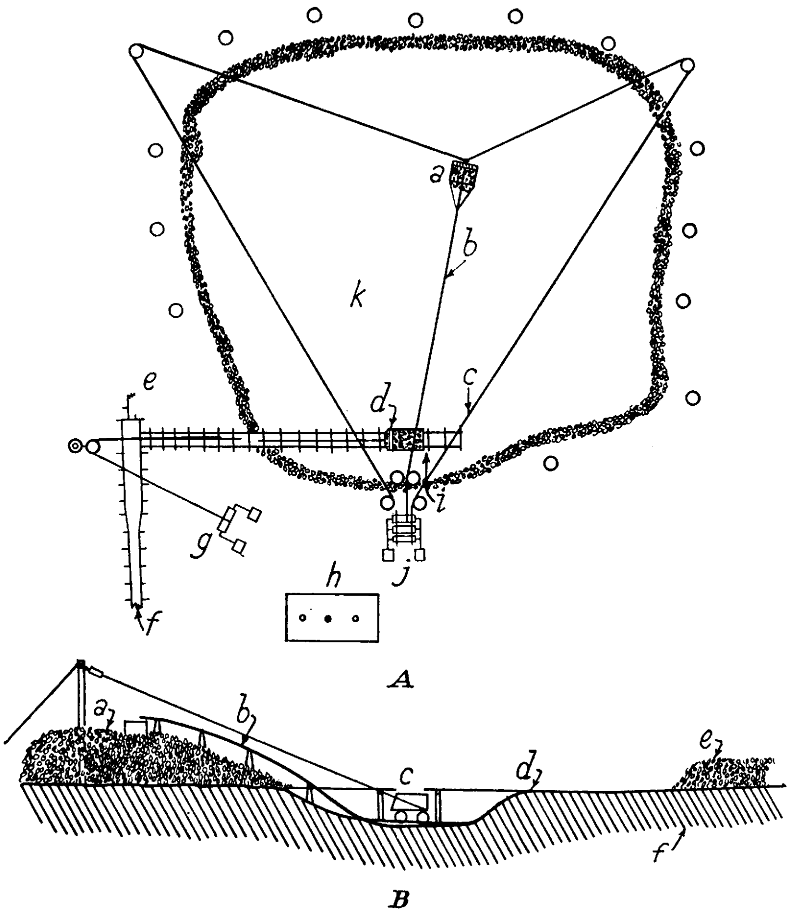

FIGURE 21.—Typical Bagley scraping and loading operation

A, Plan: *a*, Bagley scraper, 2 cubic yards; *b*, 1-inch cable; *c*, ¾-inch cable; *d*, car; *e*, dump box; *f*, sluice; *g*, 1-drum hoist, 8½ by 10 inches; *h*, boiler house; *i*, underground loading station; *j*, 3-drum hoist, 10 by 12 inches; *k*, pit about 300 feet square.

B, Section: *a*, Waste dump; *b*, incline track; *c*, station; *d*, depth of cut; *e*, gravel bank; *f*, bedrock.

With each load from the scraper the car is hauled up an incline track by cable from an auxiliary 6 by 8 or 8½ by 10 hoist, and dumps into the dump box. The use of the car incline and auxiliary hoist, while requiring additional equipment and the services of an extra engineer, has proved a saving in fuel and speeds up the scraping. It is used to advantage where the material has to be elevated about 40 feet or more above bedrock, or where other conditions may warrant. A timber or pole incline up which the scraper is dragged to the dump box is generally used in the smaller pits or where the elevation is comparatively low. A loaded scraper and car on the track incline, a sluice, and general arrangement are shown in Figures 22 and 23. Figure 12 shows the entire process.

Speed of scraper.—Where the material is dumped into the cars, with average digging conditions and everything running smoothly, 30 to 50 trips of the scraper are made per hour, whereas at certain smaller mines where the scraper delivers to the sluice this speed is materially reduced. Speed of operation is, however, governed by the length of haul, frost, and other conditions, so that the average number of trips made is much less, for the average yardage scraped into the boxes ranges from 15 to 40 cubic yards per hour.

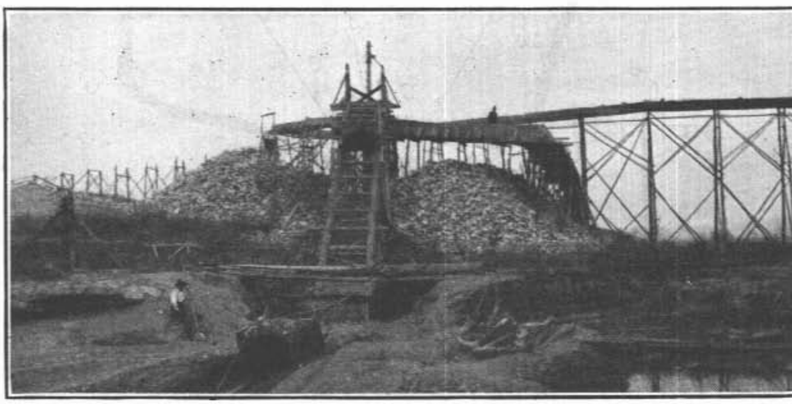

FIGURE 22.—Bagley scraper delivering load to underground station and car taking load from underground station to the sluice

Drainage of pit.—For successful scraper work the pit must be kept well drained. This is usually accomplished by an open bedrock drain, but in such localities as the Fairbanks district, where the bedrock grade is low and drains are expensive to maintain, a pulsometer or other type of pump has been found more practical for handling seepage water. The quantity is generally low, except in heavy rains, and can be handled by intermittent pumping. At a number of placers water for sluicing must also be pumped, as this insures a reliable water supply, and operators say it is probably less expensive than a ditch.

Examples of Bagley scraper operation.—The largest placers with Bagley plants are adjacent to the railroad on Goldstream and Gilmore Creeks, in the Fairbanks district (fig. 1, *33*). In 1924 five of these plants were in operation. The total depth of material worked was 15 to 35 feet, including barren overburden which was removed by stripping, leaving 6 to 8 feet of gold-bearing gravel and 2 to 4 feet of bedrock to be scraped. The pits were 80,000 to 120,000 square feet in area. The scrapers had a capacity of 1¾ to 2½ cubic yards. An average of six to eight men was employed per shift. The boiler horsepower at four of these plants was 80 to 150, and 3 to 6 cords of wood were consumed per 10-hour shift. The cost of fuel, at $10 to $12 a cord, and wages of one fireman, at $8.50 per shift, including board, averaged 4.8 cents per horsepower-hour. On the

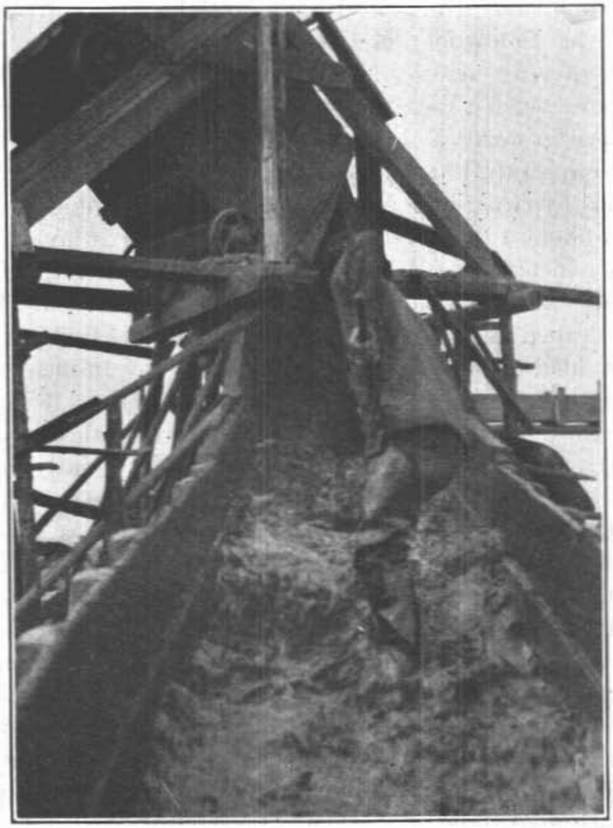

FIGURE 23.—Bagley scraper operation; car delivering to sluice

basis of 500 cubic yards of material being scraped and sluiced in two shifts (20 hours) this power cost amounts to 22½ cents per cubic yard. At one operation with a 180-horsepower boiler 5½ tons of coal, costing $6.25 per ton, were burned per shift; with attendance this cost amounts to 2.4 cents per horsepower-hour. One operation burned 1½ cords of wood per shift for pumping water for sluicing.

The cost of scraping and sluicing the gravel and bedrock ranged from 45 to 90 cents per cubic yard. At one placer where water was pumped for sluicing this power cost and sluice attendance was 15 cents per cubic yard. The combined cost of stripping, scraping, and sluicing was 25 to 50 cents per square foot, or 40 to 60 cents per cubic yard, for ground 15 to 35 feet deep. The capital invested in equipment at these mines ranges from $15,000 to about $25,000. The smaller workings in other districts have $4,000 to $12,000 invested in equipment.

Typical Bagley scraper operation at Fairbanks.—Although practice and conditions differ at different placers, they are well illustrated in the following description of a typical large Fairbanks mine. The average depth of ground mined was about 16 feet. The 5 feet of overburden were hydraulicked off, 3 feet of upper gravel were scraped to waste, and about 5 feet of gravel and 3 feet of schist bedrock were scraped and sluiced. The pit was 300 by 400 feet and was drained by two 2-inch pumps. A 4-foot (1¾-cubic yard) Bagley enlarged to hold 2 cubic yards and operated by a 10 by 12 hoist was used with 1-inch cable for the lead line and ¾-inch for the haulback lines. Three sets of cable were required for the season. The material was scraped and dumped into the car in the underground station and hauled up the track incline by an 8½ by 10 inch engine and dumped into the dump box. Three boilers, totaling 115 horsepower, produced the power. With favorable conditions the scraper made 35 to 40 trips per hour, although this was often greatly reduced by frost conditions, so that the average yardage scraped to the car was about 450 cubic yards per 20-hour day.

The dump box at the head of the sluices is 100 feet long and 4 feet wide. At the lower end this box narrows to 22 inches, where it is connected to the 22-inch sluice boxes, 6 to 10 lengths of which are used. The dump box and sluice are set on a grade of 18 inches to 12 feet and paved with block riffles (see fig. 24). An undercurrent, the same size as the sluice box and set on a 20-inch grade, is used to catch fine gold. It consists of a steel plate perforated with ½-inch holes, placed 3 inches above a burlap surface. As the burlap becomes covered with mud slime, it is taken up and cleaned every day. About 125 miner's inches of water from the ditch are used for sluicing. A dump-box man is kept busy forking out the larger rocks and preventing the sluices from being clogged.

Twelve to fourteen men constitute the average crew for two shifts; the labor and mess cost is $60 per shift. The boilers burn 4 cords of wood, costing $12 per cord, per shift. This 16-foot depth of ground was worked for 35 cents per square foot, or 59 cents per cubic yard. Detailed costs are not available, but it is estimated that the cost of scraping and sluicing the 8-foot depth of gravel and bedrock was about 25 cents per square foot, or 85 cents per cubic yard.

The operator stated that this 16-foot depth could be mined for 25 cents per square foot, or 42 cents per cubic yard, if average conditions had existed. The cost of rigging and setting up for one of these large pits is about $1,000. About $25,000 is invested in the plant and equipment.

Scraper operation in Iditarod district.—On Willow Creek, in the Iditarod district (fig. 1, *21*), Bagley operations were conducted for

FIGURE 24.—Sluice showing block riffles and special liners; also hangers for backstop as used for hydraulicking

five years by stripping about 9 feet of overburden by ground sluicing and scraping 7 feet of gravel and soft slate bedrock into a car by a 1¼-cubic yard scraper, at an average cost of 30 cents per square foot, or 51 cents per cubic yard. Scraping the 7 feet of gravel and bedrock cost 65 cents per cubic yard. With eight or nine men employed, working one shift only, an area of 40,000 to 50,000 square feet was mined in a season. A 60-horsepower boiler produced the power. No water was pumped. Wood cost $14 per cord, and 3½ cords were burned per shift.

Scraper operation at Flat Creek.—A Flat Creek plant of similar size, in ground averaging 10 feet in depth with soft slate bedrock and easy digging conditions, mined 200,000 square feet in a season at an operating cost of 25 cents per square foot, or 68 cents per cubic yard. In 1922 the same operator mined a 20-foot depth of ground from which 12 feet of overburden were stripped and the balance scraped to a car, at a cost of 50 cents per square foot, or 68 cents per cubic yard.

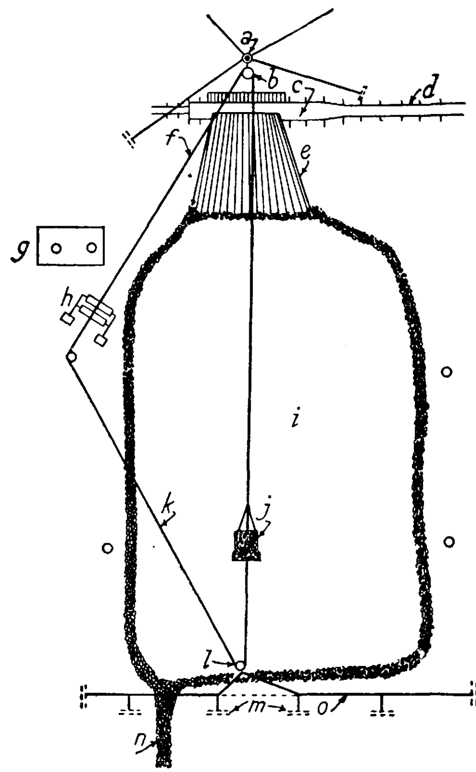

FIGURE 25.—Typical slip-scraper arrangement: *a*, Gin pole; *b*, lead sheave; *c*, dump box; *d*, sluice; *e*, timber incline; *f*, lead cable; *g*, boiler house; *h*, 2-drum hoist, 8¼ by 10¼ inches; *i*, pit, 150 by 250 feet; *j*, slip scraper, ¾ cubic yard; *k*, haulback cable; *l*, haulback sheave; *m*, deadmen; *n*, bedrock drain; *o*, 1-inch anchor cable

SLIP SCRAPERS

The operation of slip scrapers restricts them to the mining of shallower and richer deposits. Such scrapers are equipped with a full bottom, the cutting edge fitted with heavy teeth, of which there are generally five.

A typical arrangement for mining by slip scraper is shown in Figure 25. The pit is kept free of water, usually by an open bedrock drain. A two or three drum, 7 by 10 or 8¼ by 10 inches, double-cylinder hoist with a ¾ to ⅞ inch lead cable and one ⅝ or ¾ inch tail or haulback cable operate the scraper, for which a 40 to 60 horsepower boiler is used. A continuous cable system operated on a single drum has been used for dragging the scraper back and forth, but has little to recommend it. Two sizes of scrapers, holding ¾ and 1 cubic yard of loose material, respectively, are in use. Although the scraper must be fully loaded at the back to keep it from upending, the load delivered to the sluice is often but one-half to three-fourths its capacity.

To assist the scraper in digging its load, the rear end must be raised so that the teeth can sink into the ground. Two men are required for this, one at each of the poles or long handles which fit into sockets at the upper rear corners. When the scraper is loaded, these poles are withdrawn (fig. 26). The loaded scraper is then dragged to the far end of the pit and up a timber incline, at the top of which the teeth engage a timber, upending the scraper and dump-

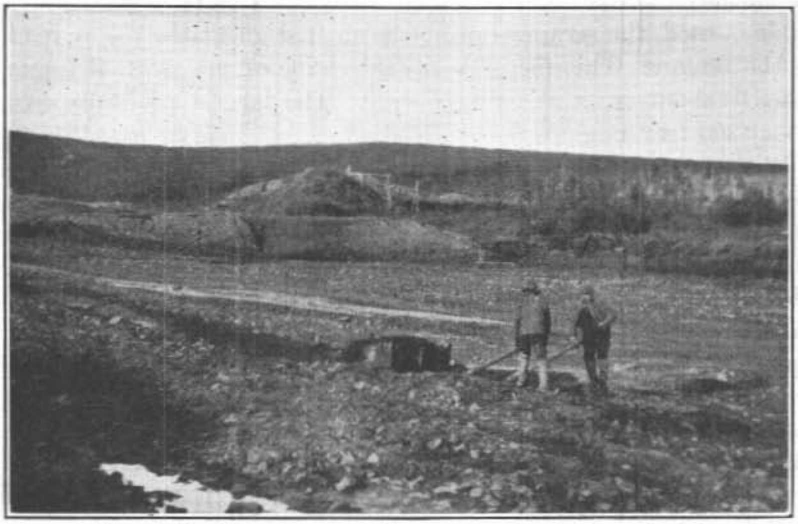

FIGURE 26.—Slip-scraper operation; scraper has just been loaded

ing its contents into the dump box, where one man is usually required to see that the scraper empties properly and to look after the sluicing. The scraper going up the incline and the usual sluicing arrangement are shown in Figure 27.

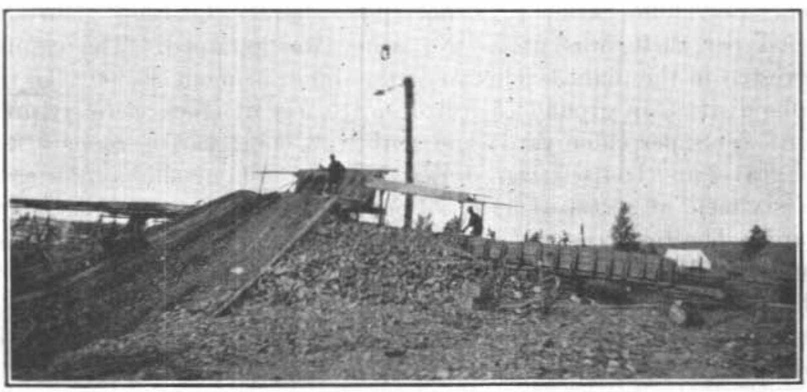

FIGURE 27.—Slip scraper traveling up incline to sluices

The scraper is then dragged back and the procedure repeated until a cut about equal to its own width (4 to 4½ feet) and about 1 foot deep and the length of the pit has been completed. The haulback sheave (fig. 25) is then shifted by hand along the anchor cable shown to the position for the adjoining cut. This can be improved by the use of a long bridle cable extending along the entire lower end of the pit and the shifting of the sheave, accomplished by cables operated from the niggerhead or extra drum on the hoist. This sheave can be anchored and shifted in various ways, but as only one haulback cable is used, the scraper can not be shifted about the pit as readily as the Bagley. This fact governs the shape of pits, so that they are usually about twice as long as wide. The largest pits scraped are about 300 feet long.

With a haul of 150 to 300 feet, the ¾-cubic yard scraper can make 10 to 30 trips per hour, but under average conditions will only deliver to the dump box 50 to 125 cubic yards per 10-hour shift. In difficult digging ground, or in the scraping of bedrock, a heavy plow is attached to the scraper to loosen the material so the scraper can pick it up. At the larger operations, where 40,000 to 65,000 square feet of a pit are mined in a season, the crew for each shift generally consists of an engineer, fireman, dump-box man, two men in the pit, and one or two roustabouts, while at some of the smaller operations the crew may be but three or four men.

Slip-scraper operation in Innoko district.—In the Innoko district (fig. 1, *22*) a pit 65,000 square feet in area was mined, a 4-foot depth of overburden and upper gravel being first removed by ground sluicing for 14 cents per cubic yard. Four feet of gravel and bedrock were then scraped into the boxes in 95 days with a ¾-cubic yard scraper by a crew of 13 men for 23 cents per square foot, or $1.55 per cubic yard. Mining the entire depth of 8 feet cost 87 cents per cubic yard. A 40-horsepower boiler, burning 1 cord of wood per shift, was used. No water was pumped. The capital invested in the plant, exclusive of the ditch, is about $6,500. In the same district, in ground 16 feet deep, 10 feet of muck were stripped for 7 cents per cubic yard; and with a ¾-cubic yard scraper 6 feet of gravel and bedrock were scraped in 74 ten-hour shifts by a crew of six men, at a cost of 30 cents per square foot, or $1.35 per cubic yard. The total cost was 32 cents per square foot, or 54 cents per cubic yard. The pit was 150 by 230 feet in area. A 8¼ by 10 three-drum hoist with a 50-horsepower boiler was used, about 500 square feet of bedrock being scraped per cord of wood. No water was pumped. The cost of the equipment is about $7,000.

Slip-scraper operation in the Hot Springs district.—In the Hot Springs district (fig. 1, *30*), in ground 11 feet deep, 4 feet of muck and top gravel were ground sluiced off for 15 cents per cubic yard; the pit was 290 feet long and 140 feet wide. With a 1-cubic yard scraper 7 feet of gravel and bedrock, or 10,500 cubic yards, were scraped in and sluiced in 110 days, at a cost of 35 cents per square foot, or \$1.32 per cubic yard. Only one 10-hour shift was worked per day by a crew of seven. Mining the entire 11 feet cost 89 cents per cubic yard. About 100 miner's inches of water, supplementing the small supply from the ditch, were pumped. Two 40-horsepower boilers were used and burned 4 cords of wood per shift.

CABLEWAY EXCAVATORS

Cableway excavators for placer mining have been little used in Alaska. One mine was recently worked on Goldstream Creek in the Fairbanks district (fig. 1, *33*). At this placer, as at the several other places where the excavator was used, conditions adverse to cheap operation were encountered. Frozen ground and difficult slabby bedrock were the main handicaps, and, as seepage water and

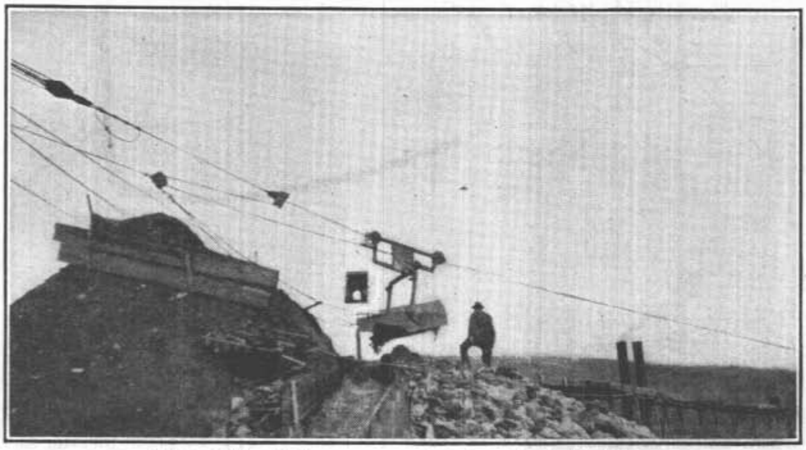

FIGURE 28.—Cableway excavator dumping into sluices

water for the sluices had to be pumped, low costs obviously were impossible.

Comparison with steam scrapers.—Cableway excavators combine certain advantages of the steam scraper with the added advantage of conveying, elevating, and automatically dumping the material into sluices without the use of additional machinery; however, they lack the mobility of Bagley scrapers and can not handle a pit of as large an area or of as favorable proportions. They have, however, the advantages of requiring less power, labor, and equipment and a lower maintenance cost than steam scrapers operated under similar conditions.

Types of cableway excavators.—Several types of cableway excavators are on the market, differing mainly in the type of the bucket and its control. The ¾-cubic yard bucket is used in Alaska, although various other sizes are obtainable. The bucket is somewhat similar to the toothed slip scraper and is attached to the carrier by a swinging bail. It is shown in Figure 28 with the traveler block at the stop button and the chains being pulled through a block on the haulage cable, dumping the bucket. Another type is a combination affair, the upper side of the bucket being a bottomless scraper. This bucket is attached to the carrier by flexible chains which overcome some of the difficulties encountered with a bail connection.

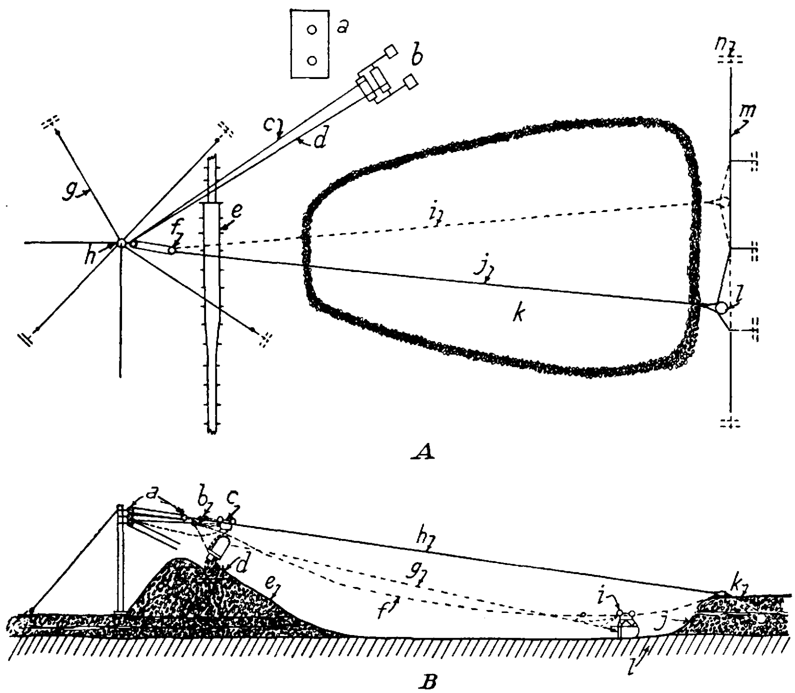

FIGURE 29.—Sketch of cableway excavator mining

A, Plan: *a*, Boiler house; *b*, 2-drum hoist; *c*, tension cable; *d*, load cable; *e*, dump box; *f*, sheave; *g*, guy cables; *h*, gin pole; *i*, former position of *j*; *j*, 1-inch track cable; *k*, pit 250 feet long; *l*, sheave; *m*, 1¼-inch cable; *n*, deadmen.

B, Elevation: *a*, Tension cable and blocks; *b*, stop; *c*, bucket dumping; *d*, dump box; *e*, waste; *f*, track cable; *g*, load cable; *h*, track cable; *i*, bucket-loading traveler block; *j*, pay gravel; *k*, anchor; *l*, bedrock.

DESCRIPTION OF TYPICAL CABLEWAY SYSTEM

Figure 29 shows a typical cableway excavator at work. The tension cable operates the tension or fall blocks at the gin pole, tightening or slackening the track cable. At its lower end the track cable is shifted by hand along a series of short bridle cables. Starting with the empty bucket near the top of the incline-track cable, which is now tight, the haulage cable is released, allowing the carrier and bucket to travel down the track cable by gravity, saving power.

When the excavator is over the point of excavation, the tension cable is released, lowering the track cable, carrier, and bucket into the pit. The bucket is then pulled forward by the haulage cable and loaded, and the tension blocks are drawn up, tightening the track cable and lifting carrier and loaded bucket with it. As the bucket clears the ground it is pulled forward and up at the time the track cable is tightening, and is conveyed and discharged into the dump box. The loaded bucket on its way to the sluices and other details are shown in Figure 30. Although speed of operation depends on the digging conditions and length of span, 30 to 40 trips can be made per hour under average favorable conditions.

As the line of cut is governed by the position of the lower end of the track cable, the cuts radiate to a common center—the gin-pole end. This results in a wedge-shaped pit, which is generally two to

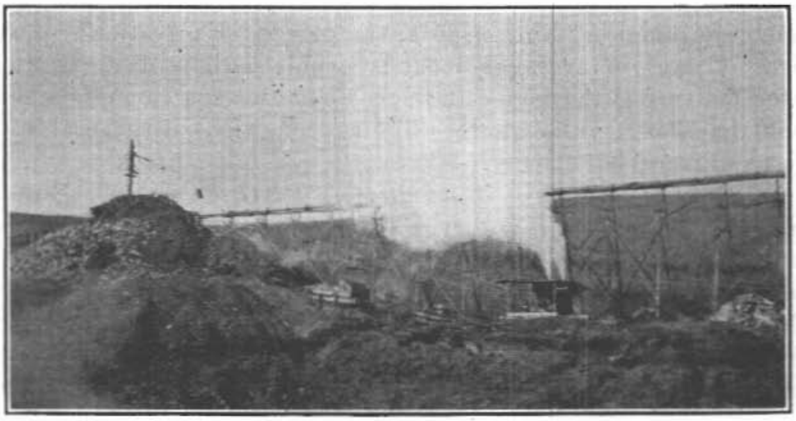

FIGURE 30.—Cableway excavator plant

three times as long as the average width. The pits worked are seldom over 250 to 275 feet long and require a cable span of 325 to 400 feet. Longer spans have been found impractical.

EXAMPLES OF CABLEWAY OPERATION

The stripping of overburden, draining of the pit, and sluicing of the gravel are done as in steam-scraper mining.

Cableway excavator on Goldstream Creek.—At a mine on Goldstream Creek 7 feet of overburden were stripped and 10 feet of material excavated. Frost in the ground and difficult bedrock, a hard slabby schist alternating with strata of soft schist, retarded the work and required men in the pit to attend the bucket, which is otherwise unnecessary. The pit was 240 feet long, 150 feet wide at the lower end, and 75 feet wide at the upper. The cable span was 325 feet. Seepage water and water for sluicing had to be pumped.

The excavator was operated by an 8 by 10 two-drum hoist. One-inch track cable was used. While this difficult bedrock was being excavated the excavator made 30 trips per hour, and while it was working in the thawed gravel it made as many as 40 trips. The operating conditions were too irregular, however, for obtaining definite data. Eleven men were engaged for the two 10-hour shifts.

Cableway excavator on Twin Creek.—On Twin Creek 8 feet of gravel and about 2 feet of bedrock were excavated. The lower part of the gravel contained large angular slide material, and bedrock was mainly a blocky hard gneiss. The pit was 325 feet long and 120 feet wide at one end and 70 feet at the other. A cable span was 450 feet long; this was found to be too long. A ¾-cubic yard excavator was operated by a 7 by 10 inch hoist; the 30-horsepower boiler burned only ½ cord of wood per shift. The lower end of the track cable was shifted by cable from the hoist. No water was pumped. Nine men were employed. Excavation required about 70 days, or averaged about 200 cubic yards a day, the excavator delivering the material faster than the one dump-box man could handle it, although the digging conditions in general were most unfavorable.

Cableway excavator on Gold Bottom Creek.—On Gold Bottom Creek, in the Yukon Territory, a ¾-cubic yard combination bucket was successfully used. The ground was 18 feet deep, wet, but partly frozen, with large quartz bowlders lying close to bedrock, which was hard, tight, and slabby. Four feet of overburden were scraped off, with the scraper side of the bucket used as a bottomless scraper, piling the material on the sides of the cut. Eleven feet of gravel were next excavated and dumped to waste. Three feet of gravel and 1 to 2 feet of bedrock were then excavated and put through the sluices. The pit was 100 feet wide and 200 feet long. Working one shift a day the excavating took 56 days. From 30 to 60 trips (40 on an average) were made per hour, or about 200 cubic yards, place measurement, were handled per shift. The crew consisted of an engineer, a fireman, and one man for general work. About ¾ cord of wood per shift was burned for operating the excavator.

Costs.—No reliable data on costs for these placers could be obtained, but with favorable conditions the cableway excavator should do wŏrk cheaper than steam scrapers. The excavator with carrier costs about $1,200. A new complete outfit would cost $7,000 to $10,000, which could be cut about one-half if some secondhand equipment was used.

DRAG-LINE EXCAVATORS

The drag-line excavator is a self-contained digging machine mounted upon skids and rollers or equipped with caterpillar traction. The bucket is operated from the main engine by cable over a series of sheaves and hangs from the end of a long boom. The angle at which this boom sits is readily adjustable, according to the requirements. By means of a turntable and swinging engine the machine can be rotated horizontally through a complete circle. The toothed drag-line bucket is lowered into the cut, pulled forward by a haulage cable and filled and hoisted to the end of the boom; the machine is then rotated to the dumping point, and the bucket dumped. The standard sizes of drag-line excavators are built with booms 40 to 125 feet long and buckets holding 1 to 4 cubic yards. Although the drag-line excavator can not dig as heavy material, it has many distinct advantages over the steam shovel. As it has a wider digging radius fewer moves are necessary. As it rests on the surface of the ground, it can deliver the material at a great elevation and dump directly into the sluice, dispensing with any intermediate device for conveyance or elevation. This feature is important in open-cut mining. The drag line is well adapted for mining unfrozen gravel with a few large bowlders, underlain by a comparatively soft, regular bedrock. At work, it is less mobile than the Bagley scraper but has many advantages over all types of scrapers and other excavators in speed of operation, low cost of power, labor, and maintenance. As it can be moved quite readily, especially when equipped with caterpillars, and quickly set up, it has a useful place in mining isolated small areas of placer ground. The bucket is tight and can be used under water, but under average conditions it would not clean bedrock properly unless the pit is drained.

Two drag-line excavators and one combination drag-line steam shovel are operated in Alaska. Other drag-line excavator installations are under consideration.

DRAG-LINE EXCAVATOR ON WILLOW CREEK

A class 14 Bucyrus drag-line excavator has been operated for the past six years on a low bench on Willow Creek in the Iditarod district (fig. 1, *21*). It is equipped with a 60-foot boom and 1½-cubic yard Page bucket, which weighs about 3,700 pounds. Power is produced by a 60-horsepower boiler. This excavator has a 14-foot turntable, and is mounted on skids and rollers. The deposit consists of about 12 feet of moss-covered muck and 6 feet of light gravel. Bedrock is a soft slate, the upper portion being decomposed to a blue sticky clay. The ground is virtually all frozen before the muck and upper gravels are removed by ground sluicing and hydraulicking; the remaining gravel thaws naturally. From 4 to 5 feet of gravel and about 1 foot of bedrock are handled by the excavator. The pit has natural drainage.

The average pit is 110 to 120 feet wide and 150 feet long. It requires five positions of the machine, the center of the machine being always kept 65 feet, or the dumping reach, from the center of the sluice hopper. From each position an arc cut 30 to 50 feet in width is made, and the bucket can be thrown about 18 feet beyond the digging reach (62 feet) to take out the corners or outlying areas of the pit. The system of making the various cuts is complicated, for from each position there is an overlapping area which can be reached. After the area most workable from the position

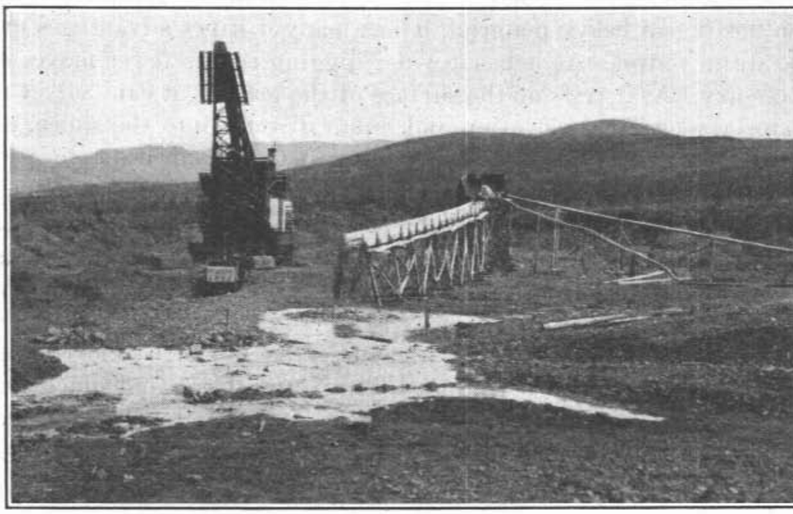

FIGURE 31.—Drag-line excavator bucket loading

has been dug, heavy planks are placed on the ground ahead of the machine, the bucket is thrown out for an anchorage, and the machine is pulled ahead over rollers to the next position, the move requiring but a few minutes. Figure 31 shows the bucket being loaded.

The sluice hopper is 14 feet long, 8 feet wide at the bottom, and 6 feet deep; to it is attached a 16-foot length of sluice that widens to 2 feet at the lower end. Both of these rest on a heavy timber frame mounted on wheels so they can be moved along a wooden track to the next pit. This track is 8 feet beyond the edge of the pit and parallels it, the sluice hopper being placed opposite the center of the pit. The grade of the hopper and following sluice is 20 inches. The remaining sluice boxes, usually about 10 lengths, are 2 feet wide and are set on timber trestles on a grade of 13 inches. The riffles are Hungarian manganese cast steel.

Water supply.—An average of about 160 miner's inches of water under low head is supplied to the sluices from two ditches. The dump-box man, using a giant with a 2 to 3 inch nozzle, "boils" out the material as much as possible before it passes out of the hopper. During periods of low water supply the operation may be reduced to half time, when the water is impounded and used intermittently for periods of one and one-half to two hours at a time. The clayey material lying on bedrock is difficult to sluice, and much of it passes through to the dump in large chunks.

Production and cost of operation.—The excavator normally digs about 60 cubic yards, or 40 buckets, per hour, which must be reduced during sluicing with a curtailed water supply. The clean-up can be made, and the machine and boxes moved ahead and set up again in two shifts. From 15,000 to 20,000 square feet of pit are dug from one set-up in five to seven shifts. The excavator is operated only one shift, and the average crew consists of an engineer, a fireman, a dump-box man, and two roustabouts; the cost of labor and board for this crew is $57 per day. The boiler burns 1¼ cords of wood per 10-hour shift, costing $25. The cost of repairs and replacement is very low. A royalty of 25 per cent of the gross gold production is paid for the use of the equipment and the lease of the claims.

From 100,000 to 150,000 square feet of bedrock are mined in a season, and the excavator operations are limited to the area which can be ground sluiced. In 1922, a season of good water supply, 130,000 square feet or 67,400 cubic yards of overburden were stripped at a cost of 4.7 cents per square foot, or 9 cents per cubic yard. In 52 days, working one 10-hour shift per day with seven men, the excavator dug 24,100 cubic yards of gravel and bedrock averaging 5 feet in depth. The cost of excavating and sluicing this material was 28 cents per cubic yard. The combined cost for a total depth of 19 feet, exclusive of royalty, was 11 cents per square foot, or 16 cents per cubic yard. Costs during previous years are stated to have fluctuated very little and to compare closely with these.

Suggested improvement.—There are numerous ways of setting up and operating the excavator, and while the above system has given good results it could be speeded up and simplified by mounting the entire sluice on a track so that with each move forward of the excavator the sluices could be pulled along an equal distance. Caterpillar traction increases mobility and gives other advantages which may, however, not be justified because of the higher cost.

Drag line.—The drag line used at this placer is well adapted to Alaska conditions. It was a secondhand machine, purchased in the United States. A machine of its size usually has a 60-foot boom and a 2-cubic yard bucket and can be obtained to operate by any kind of power. The steam-operated machine with skids and rollers costs $25,250 at the factory and weighs 52 tons packed for export. With caterpillar traction the cost is about $34,000 and the weight 88 tons. To adapt this size to a wider range of work, optional combinations are offered, such as an 80-foot boom using a 1¼-cubic yard bucket.

DRAG-LINE EXCAVATOR ON NOME AND CARIBOU CREEKS

A locally constructed drag-line excavator was operated on Nome Creek in the Fairbanks district. It is equipped with an old 6 by 8 hoist, 20-horsepower boiler, timber gantry, 40-foot boom, and a ½-cubic yard bucket, all mounted on a timber frame. It is moved over log rollers (fig. 32). Medium-size gravel averaging 9 feet

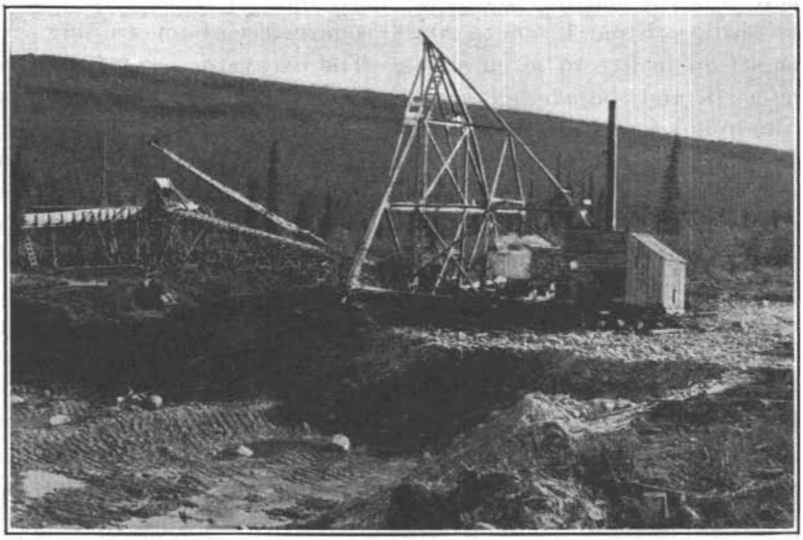

FIGURE 32.—Locally constructed drag-line excavator, Nome Creek, Fairbanks district

in depth and about 3 feet of schist bedrock are excavated, the bucket dumping into a car which conveys the material up a low incline to the sluices. Three men are employed, and about 100 cubic yards are handled in a shift. The cost of operation is stated to be about 50 cents per cubic yard. This machine recently collapsed, and the operations have been suspended.

A "20B" combination drag-line steam-shovel machine with ¾-cubic yard bucket was recently operated on Caribou Creek in the Salchaket district (fig. 1, *34*). The operation was not visited by the writer, but it is reported that about 15 feet of overburden and barren gravel are first stripped with the drag-line attachment. The lower or pay gravels of about a similar depth are then dug by the steam shovel, dumped into a self-dumping bucket, and hauled up an incline cable to the sluices. The cost of such mining must be high, as it is impossible to handle such a depth of gravel economically by this means of excavation and conveyance. The digging radius of this size of machine is too small, and the intermediate conveyance of the material to the sluice delays operation and adds greatly to the cost.

DRIFT MINING

Drift mining is used in mining rich, moderately thick, pay streaks overlain by a deep barren overburden or one too low grade to justify removal. In Alaska placers the method is best applied to mining deep, permanently frozen creek and bench deposits, where the gold is chiefly found near or in the upper few feet of bedrock, or to mining deep unfrozen bench deposits under conditions that prohibit mining by other methods.

Drift mining was at one time of great importance to the Nome, Fairbanks, Hot Springs, Koyukuk, Ruby, Tolovana, and other districts, but is now restricted mainly to some small mines in the Yukon-Tanana Valley or interior districts. Few large blocks of virgin ground which are adapted to this method remain, and most of the present drifting is in ground left by former mining, where the lower-grade pay that was left behind or small isolated blocks and pillars are being mined. Numerous failures have resulted from reopening old ground. New shafts have often been sunk on what was supposed to be a suitable block of pay gravel only to find on drifting that much of the gravel had been removed, or was too low grade, or the quantity of "pay" was too small to repay the expense of development. Water which could be pumped only at excessive costs may also be encountered in quantities. Old shafts and workings are sometimes used in mining small areas that could not otherwise be worked at a profit.

Under present conditions most drift mines do not follow any definite system of mining, and with the old equipment used at most of these mines there is small opportunity for improvement. Formerly, some large drift mines employed 30 to 50 shovelers underground and mined 100,000 to 200,000 square feet of bedrock per season. There are now less than a dozen properties where 15 to 20 men constitute the entire crew, and these seldom mine more than 50,000 square feet of bedrock per season. Numerous small drift mines employ crews of two to six men. The average mine works one shift per day and employs 8 to 10 men. These comprise a hoist man, who is usually also the fireman, a general surface man, and six to eight miners; such a crew will mine 10,000 to 30,000 square feet of bedrock per season.

Most Alaska drift mining has been conducted in frozen deposits 25 to more than 200 feet deep, opened by shaft, and the following account deals principally with such operations.

Some frozen deposits 15 to 18 feet deep have been drifted in a small way, although many of these shallow deposits were better adapted to mining by other methods. The numerous variations in past practice have been described by various writers, therefore only the more representative methods and those of recent development are described here.

TYPES OF DRIFT MINES

Drift-mining operations can be divided into summer and winter mines; both are developed in much the same way. At winter mines the "pay dirt" is stored in dumps until water for sluicing becomes available in the spring. Where the ground is permanently frozen, winter mining usually requires little or no timbering. In some places winter is the best time for mining unfrozen ground that is wet during the summer, or for mining small patches left in old mines. Rethawing and rehandling the material in the spring, before it can be sluiced, often add decidedly to the cost. Other disadvantages of winter mining are the tying up of capital through the winter, the larger steam requirements, and the uncertainties of recovering gold in sluicing.

Most drift mines are now worked in summer, although some are active throughout the year. The plant is erected, the shaft sunk, and all development and preparatory work usually done during the winter, to have everything in readiness by spring.

EQUIPMENT FOR DRIFT MINES

The equipment used differs widely in size and kind, and its selection depends largely on the amount and condition of old machinery that is available and the finances of the operator. Many plants are equipped with old boilers, hoists, pumps, and other equipment which has seen many years of service at other mines or was moved from district to district after the gold rushes. This old and often worn-out equipment has low efficiency, but there are few instances where the installation of new modern equipment for drift mining would now be justified.

The smaller mine, as a rule, is equipped with a 12 to 30 horsepower vertical or marine-type boiler, and a 6 by 6 or 7 by 7 inch single-cylinder vertical hoist. At the larger mines the boilers are mostly of return-flue type and range from 30 to 60 horsepower, with a 7 by 7 vertical or a 5½ by 8 double-cylinder hoist. Larger boilers are now rare; two or more small ones are used instead. At many mines working only one shift the thawing of gravel or pumping of water for sluicing is done after shift, and one small boiler suffices for all purposes.

The average outfit contains 10 to 50 steam points, or "sweaters," hose and pipes, a self-dumping bucket and carrier, a small mine pump, cars, wheelbarrows, tools, cable, blocks, blacksmith's tools, and sluices, with a small ditch or a pump for pumping water for sluicing. An outfit that costs $3,500 to more than $10,000 when new can now be pieced together from old outfits at practically the buyers' own terms. A complete secondhand 30 to 40 horsepower plant, which originally cost $7,000 to $10,000, can now often be purchased for $500 to $2,500. Old ditch lines are also at the service of many of the present mines.

Most operators neglect to insulate the boilers and steam lines, although they are aware that insulation will quickly repay the expense, as evidenced in the smaller fuel consumption of plants where it is done. Lack of insulation and especially the poor efficiency of old equipment make steam costs high. The average small drift mine in the interior districts burns ½ to 1½ cords of wood fuel per shift, costing 2½ to 7 cents per boiler horsepower-hour. Near Nome crude oil was burned in the boilers.

METHODS OF DEVELOPMENT

The methods of opening a placer drift mine, which are quite similar to those employed in opening flat-vein or bedded deposits, are governed chiefly by the topography, the character and dimensions of the pay streak, the gold content and its distribution, and the contour and grade of the bedrock. These features should be determined by previous prospecting or other work before a block of ground can be properly opened. The customary practice in Alaska drift mining involves sinking a shaft, blocking out the ground with drifts and crosscuts, thawing the gravel and bedrock, mining and hoisting it to the surface, and conveying it to the sluices where the gold is recovered. Where topography permits, as on some of the benches, the placer may be worked through an adit or tunnel.

DEVELOPMENT BY SHAFTS

The shaft is generally sunk at about the center of the area to be mined, with consideration for the slope of the bedrock. These shafts are usually 6 by 6 or 7 by 7 feet in the clear. With two men working in the shaft, 5 to 8 feet per shift can be sunk through muck. The muck or alluvium is usually thawed before it is excavated, but frozen muck is also dug with a pick. When thawed, it can practically be bailed out of the shaft. Frozen gravel is always thawed before it can be dug. The shaft is continued 6 to 14 feet and more into the bedrock, depending on bedrock conditions and the system of mining to be used, in order to provide drainage and room for a station.

Timbering shafts.—For winter work a shaft seldom requires timbering, except possibly a little cribbing at the surface. For summer work in solidly frozen ground the first 15 or 25 feet below the collar may require light crib timbering, with a square-set at the bottom and a little cribbing above the set. However, in average ground and especially in the deeper deposits, the shaft is generally fully timbered. Where available, round spruce poles 3 to 6 inches in diameter are used for crib timber. The timbers are cut to length, notched on one side at each end, and placed skin to skin. One cord of 16-foot poles of the average size used will crib about 8 feet of shaft. The space between the crib and the frozen ground is then filled with gravel (moss is generally used in muck), and the filling is tightly tamped into place. Care and experience are necessary to place the cribbing properly and tamp the material behind it, and even then thawing of the gravel may cause the cribbing to "corkscrew" or "jackknife." The direct pressure on the cribbing is, however, usually very light. Deep shafts properly timbered have been brought back in service after more than 15 years with little repair, while others were retimbered, although the old timbering was still in alignment.

The bottom of the shaft or station is timbered with a square-set. The average square-set is made of 10 to 14 inch round timber, although at some of the deep mines timber 20 to 24 inches in diameter is sometimes used.

On the Seward Peninsula, where timber must be shipped in, sawed lumber is used. One 63-foot shaft near Nome, 4 by 4 feet in the clear, was timbered at the bottom with a square-set, for which 10 by 10 inch posts and 10 by 14 caps were used; above this it was timbered with 2 by 4 inch lumber, notched and placed one above the other like well curbing and spiked together. Vertical pieces were placed in each corner and horizontally braced. This shaft cost about $500 to sink and about $700 to timber, with lumber costing $108 per thousand board feet at the mine.

The cost of sinking the average working shaft where little or no timbering is necessary ranges from $6 to $12 per foot, varying mainly according to the depth and the character of the deposit. Shafts fully crib-timbered and with a square-set at the station cost $10 to $20 per foot, while some deep shafts sunk in difficult ground may cost $25 or more per foot.

Water in the shaft.—In mining solidly frozen ground, water is produced from thawing of the gravel, or some may seep down the shaft. The quantity is generally small and can be easily handled with a 1 or 2 inch single or duplex pump. At most mines only a few hours pumping each day is required. Steam injectors are successfully used at some mines where the volume of water is small and the lift is not too great. In some mines, when thawed channels are encountered or wet unfrozen ground is mined, the amount of water to be pumped is much larger and may prevent mining.

Shafts on Dome Creek.—On Dome Creek in the Fairbanks district a 138-foot shaft 7 by 7 feet in the clear was sunk through 115 feet of muck, 15 feet of gravel, and 8 feet of bedrock, with an additional 6-foot sump below. The muck was picked for 75 feet, two men in the shaft averaging 6 feet per shift. The remaining muck and gravel were thawed by the use of nine 9-foot steam points; a thaw was completed in muck in 10 hours and in 12 hours in gravel. Average sinking progress in the gravel was 4½ feet per shift. The entire shaft was crib timbered by six men in six days after the cribbing was cut. Sixteen cords of poles were used, costing $192; the square-set in place cost about $100; and wood fuel, $256. The entire cost of timber, labor, and fuel for the shaft including the sump was about $2,000, or $14.50 per foot. Three hundred feet of timbered and one hundred feet of untimbered drift cost $8 and $6 per foot, respectively. The total cost of development, erection of plant, and all preparatory work was about $6,500.

One of the best records in shaft sinking was made some years ago at the mouth of Dome Creek, where a 171-foot shaft was sunk without timbering in 21 days (single 10-hour shift), with three men in the shaft and two on the surface, the thawing being done on the off shift.

DRIFTING

Where conditions permit, drifts are sometimes driven 300 feet, but more often 200 feet or less, up and down stream from the bottom of the shaft, depending chiefly on the slope of the bedrock. Longer distances increase underground transportation costs and may not allow proper drainage of the workings.

In a wide pay channel drifts may be driven from the shaft in four directions, but in narrow irregular deposits it is advisable to follow the pay. Crosscuts are driven at 50 to 100 foot intervals to the limits of the pay. Figure 33 shows a longitudinal section of a typical interior drift mine and Figure 34 a plan of underground workings and a surface plan. In driving drifts or crosscuts thawing is sometimes done with one, but usually with two to four, steam points. Long points may be used, but as the advance averages 6 to 10 feet per shift it is better practice to use shorter points and thaw only the distance that can be excavated by the shift.

In average frozen ground only a few sets of timber each side of the shaft are required, but often the entire drift is timbered. Three-

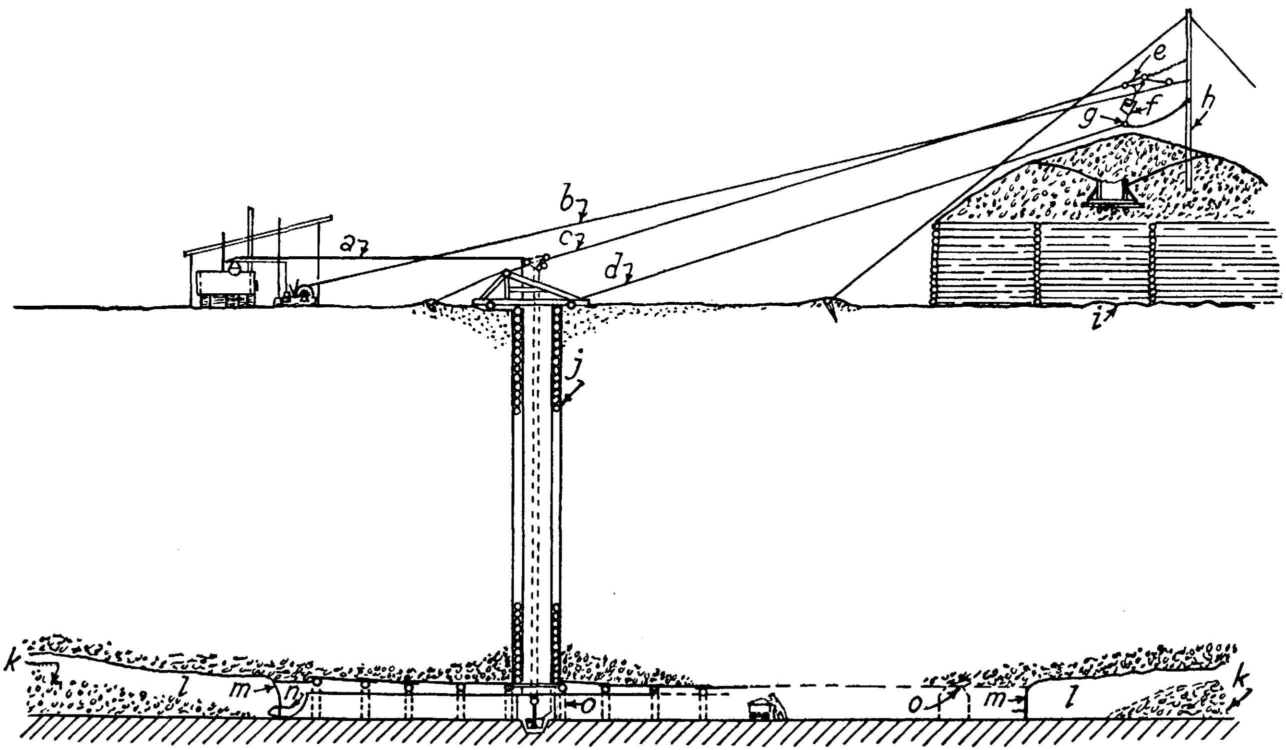

FIGURE 33.—Section of a drift mine: *a*, Steam line; *b*, hoisting cable; *c*, traction cable; *d*, guide and tripping cable; *e*, carrier; *f*, bucket; *g*, trip; *h*, gin pole; *i*, crib-timbered dump; *j*, crib timbering; *k*, cave from roof; *l*, stoped out; *m*, working face; *n*, steam points; *o*, square-set

piece sets of two posts and a cap, spaced 5 to 8 feet apart, are used. Round 5 to 8 inch timbers and light 2 to 4 inch pole lagging are generally large enough, for the timbers usually have to support only gravel which may slough from overhead. Side lagging is seldom necessary. Where bedrock is soft, mudsills or foot blocks are used. In some mines "swelling" ground, usually from release of pressure and wet thawed streaks, causes breakage of timber. Swelling can be lessened by giving the posts a wider spread at the base, removing the lower lagging, and picking down material behind the timber. The average cost of untimbered drifts and crosscuts is \$5 to \$8 per linear foot; the cost for timbering is \$2 to \$4 per foot.

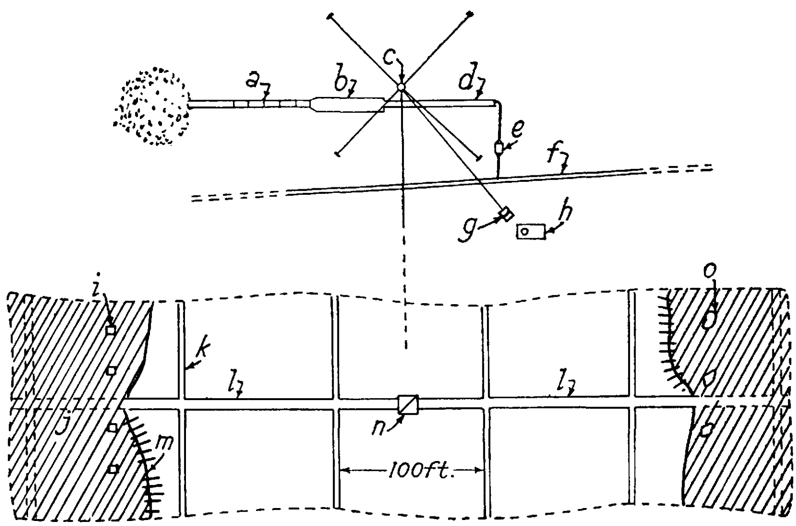

FIGURE 34.—Underground and surface arrangement of a drift mine: *a*, Sluice box; *b*, dump box; *c*, gin pole; *d*, elevated flume; *e*, pump; *f*, ditch; *g*, hoist; *h*, boiler: *i*, rock-filled timber cribs; *j*, stoped out; *k*, prospect drifts; *l*, main drift; *m*, steam points; *n*, shaft; *o*, unthawed pillars

MODIFIED LONGWALL METHOD

In a few former Alaska drift mines mining proceeded from the shaft, but customary practice is to work toward the shaft, using a modified form of the method that is known in coal mining as "long-wall retreating." This practice keeps the men away from the "stoped" areas and permits waste to be piled behind. While one face is being thawed another is being excavated.

The height of the working face is governed chiefly by the thickness of the pay and ranges from 4 to 8 feet but averages 5 to 6 feet, including 1 to 3 feet of bedrock. Faces smaller than 4 feet are usually not economical on account of cramped working conditions. At several mines two or more strata of pay gravel, separated by thick barren gravel or muck, were mined separately. In a few instances a thickness of 20 feet and more has been mined from one level, but under such conditions some other method would have been more practical.

Streaks of muck may be intercalated in the gravel being mined and may slab off in large pieces. These usually come down slowly, giving ample warning of danger, but unless they are supported may bury the working faces. Where a fall threatens, a heavy post and short cap will generally give enough support. When necessary, pillars of frozen gravel are left or timber cribs or bulkheads 4 to 6 feet square filled with waste gravel are placed 25 to 50 feet apart along the face. It is the general practice to support the roof for about 50 feet from the face, but beyond this point the pillars or timbers in the worked-out areas are drawn and the roof is permitted to settle.

MINING FROM ADITS

Some drift mining is being done in bench deposits opened by adit. In frozen ground the development and mining methods are practically the same as with shafts. The adit is driven on proper grade, generally in bedrock, to crosscut the pay channel; then drifts are run in both directions and lateral crosscuts are driven. Mining from an adit saves hoisting, pumping, and some other shaft expenses.

In the Nizina and other districts of southwestern Alaska (fig. 1, *47*) some unfrozen bench gravels were mined from adits, these and the drifts being heavily timbered; the faces also had to be closely timbered except where the gravel was tightly packed. Only comparatively small areas were mined from each side of the adit or main crosscut. In unfrozen wet channels of heavy gravel square-set timbering may be necessary, as in early drift mining in the Valdez Creek district (fig. 1, *42*).

In loose unfrozen ground close timbering, carried as near the face as practicable, is required. One of the best systems for handling this kind of ground is a forepoling system which has been used in California at the Hidden Treasure and other drift mines.[35] Heavy posts, set on blocks or sills, are placed in a line parallel to the face and support the caps. Sharpened poles are inserted above the cap of the set nearest the face and driven along the roof and into the face as the gravel is removed. When the face has advanced, another set of timber is placed. Where the ground is unusually heavy, a false or intermediate set is used to guide and support the lagging until the regular set can be put in. A fuller description of the

[35] Browne, R. E., "The ancient river beds of the Forest Hill divide": California Min. Bur., 10th Ann. Rept. State Mineralogist, 1890, p. 452.

method will be found in Bulletin 215.[36] Bowlders and waste are piled behind in the " stoped " areas to assist in supporting the roof.

REMOVAL OF GRAVEL

At the face the gravel and bedrock are usually picked down and shoveled into wheelbarrows or cars. Scrapers have been repeatedly tried, but without success on account of the gravel being too firm or the bedrock too hard and irregular. Scraping might succeed where conditions are favorable, but if the face must be picked down by hand and the scraper used only for conveying the loosened material to the cars little appears to be gained by such a method. Picking is arduous work and could not be continued very long but for the change and relief of shoveling and wheeling. Pneumatic picks would be a great help in this respect. Blasting the face after thawing has not proved advantageous where tried but has possibilities. A method of drilling and blasting the face without thawing and scraping the material to cars has recently been successfully developed. It will be described later. Hydraulicking underground has under favorable conditions been successfully applied in some small mines but has not been adopted because of its limited application.

Tightly packed gravel is undercut by hand, usually in the upper or softer part of the bedrock. The miner then picks down the " pay dirt " and shovels it into a wheelbarrow or mine car, throwing the bowlders behind him. If the bedrock floor is rough, shoveling plates may be used to advantage. Wheelbarrows are well adapted to conditions at the smaller mines, where the drifts are short and may have sharp turns and an irregular or steep grade. Moreover, wheelbarrows require a minimum of space, hence the drifts need not be large.

Low-built cars are generally preferred at the larger mines where systematic development and mining can be done and the grade is more uniform. At some of the earlier operations at Nome, loaded cars were run onto the cage and hoisted to the surface. Most of the larger mines use both wheelbarrows and cars, the loaded wheelbarrows being wheeled to the main drift, where they are dumped into a waiting car. With this system the drift must be cut deeper in the bedrock than is the crosscut, so that the wheelbarrow can be dumped into the car without being wheeled up a steep grade. Except for the few shafts having cages, the dirt is hoisted in buckets and the loaded bucket is conveyed to the sluices by a carrier cable.

[36] Holbrook, E. A., Ageton, R. V., and Tufft, H. E., Timbering of Metal Mines: Bull. 215, Bureau of Mines, 1923, pp. 15–17.

The duty per man in picking, shoveling, and wheeling varies with the individual and his working conditions but may be 75 to 125 wheelbarrow loads per eight-hour shift, or 20 to 40 square feet of bedrock mined to a height of 5 or 6 feet, the average being about 25 square feet, or 5 cubic yards.

BUCKET HOIST

Several types of shaft buckets are used, but that in most general use is the Fairbanks self-dumping type made in sizes holding 3 to

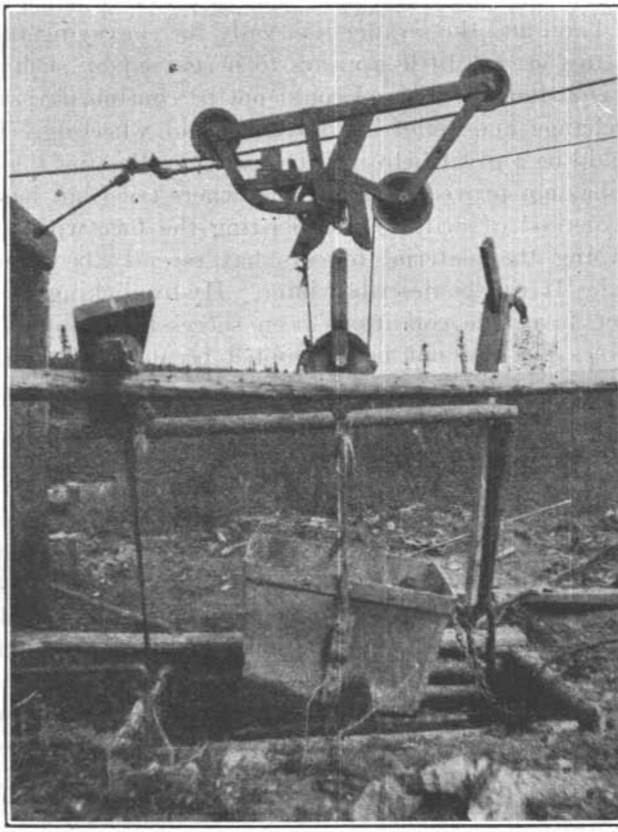

FIGURE 35.—Fairbanks self-dumping bucket and carrier

8 wheelbarrow loads. Such a bucket with carrier is shown in Figure 35. The bucket has a swinging bail and is hoisted by a cable winding through a sheave on the bail and the sheaves on the carrier suspended from the incline-track cable on the surface. A slip ring, which is attached to the bucket by a chain sling, travels along the guide or trip cable. On reaching the carrier the bucket engages a catch and is automatically locked to the carrier. Both are then pulled up the incline-track cable to a point over the dump, where the ring guide encounters a stop on the trip cable, releasing

and upsetting the bucket. This procedure is shown in Figures 33 (p. 118) and 36. Returning to the collar of the shaft by gravity, the carrier strikes a trip and releases the bucket, which is then lowered down the shaft. Men and all supplies are also carried by the bucket. At many plants the bucket when hoisting " dirt " can make a complete trip in one minute, which is much faster than the material is usually delivered.

SLUICING

At the summer mines the material as hoisted is generally sluiced at once, but the time for sluicing may be regulated by the water supply. At some mines the small amount of material mined can be sluiced in a few hours after shift. The sluicing arrangements at most mines comprise a dump box and sluice boxes set on trestles to provide the necessary grade and dump; at other mines the dump box

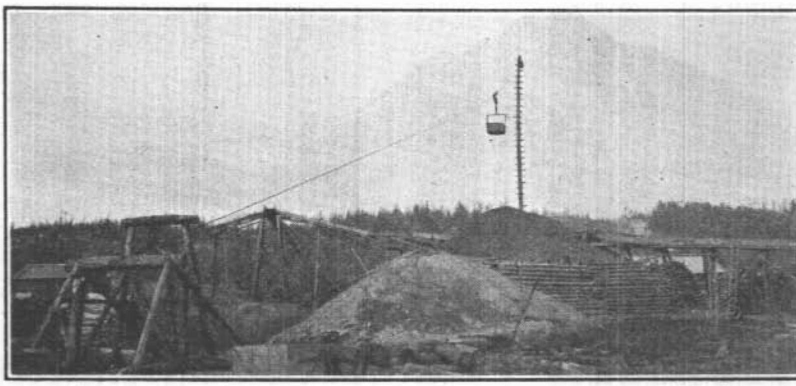

FIGURE 36.—Surface arrangement of a drift mine in interior of Alaska

and head of the sluices are often set up on an old waste dump. The dump box has a timber apron, or the sides may be built up with waste to form a chute for guiding the material from the bucket into the box. The dump box may be 20 to 52 feet long and $2\frac{1}{2}$ to 4 feet wide, set on grades of 12 to 14 inches to 12 feet. The sluice boxes are 12 to 16 inches wide and are set on grades of 7 to 12 inches, sometimes more if available. Pole riffles set lengthwise are commonly used and may be shod with strips of iron or steel. Several sets of such riffles may sometimes be placed crosswise. Undercurrents of the same width as the sluices, made of punched steel plate placed several inches above cocoa matting, may be added at the end of the sluices, but refinements for saving fine gold are often lacking.

At many drift mines clay in the gravel or on the bedrock adds to the sluicing difficulties and usually causes a loss of gold. The dump-box man forks out the large rocks, puddles the clay, and tries to disintegrate the lumps before the material passes to the sluice. Most of the gold is usually recovered in the dump box and the first or second sluice boxes, but much lumpy unwashed clay goes through the sluices to the dump, carrying some of the gold. The best method is to store on the dump such clayey material and then cut it up and wash it well by a small stream of water under pressure before it is permitted to enter the sluice (fig. 37).

As previously mentioned, water for sluicing is usually obtained by gravity flow from a ditch, but at many mines it must be lifted by a pump. Although pumping increases the cost of sluicing, it provides a steadier water supply and may save costly ditch construction and maintenance. As the season of sluicing is closed dur-

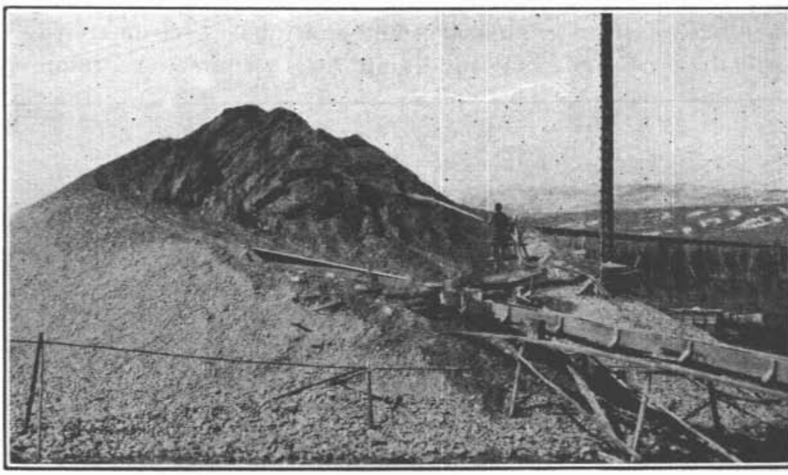

FIGURE 37.—Sluicing the dump by nozzling

ing hard freezing weather, attempts have been made to sluice during the winter by pumping warm water, but the added cost and difficulties make this inadvisable. At the average drift mine enough water for sluicing is generally available from the latter part of April to the end of September, and the quantity used ranges from 30 to 100 miner's inches.

The hoisted "pay dirt" may be stored in large dumps for sluicing, as for winter dumps; then the sluices are supported on heavy trestles and covered with boards or poles, and the material is dumped on top. When water is available, the boards are withdrawn as the material is caved, shoveled, scraped, or hydraulicked into the boxes. Unless they are hydraulicked, the winter dumps must be thawed before they can be sluiced.

COST OF SLUICING

When the material is comparatively free of clay and a steady supply of water is available from a ditch line, sluicing costs are comparatively small. Under average conditions a dump-box man is necessary; then the cost of sluicing will range from about 15 to 45 cents per cubic yard, depending on the amount of material handled and the method used. At one mine in the Ruby district about 30 cubic yards of clayey gravel are mined per day of one shift. This gravel is stored on the dump for three days, then one man hydraulics it and puts it through the sluices in one shift at a cost of 20 cents per cubic yard. The water for the 1-inch nozzle used is pumped. In the Fairbanks and other interior districts the average cost for sluicing is considered by many of the operators to be about 10 per cent of the cost of drift mining.

THAWING

In the first placer mining in Alaska frozen gravel was thawed with wood fires or hot rocks, and this method is still used at a few small isolated mines. Hot water was later used at a number of mines. With these few exceptions, the thawing in drift mines is done with steam under pressures of 90 to 110 pounds at the boilers. The steam is conducted down the shaft and to the workings through pipes from which connections are made to the various crossheads or batteries with pipe and steam hose. Each crosshead delivers steam to 4 or 5 points; a valve and hose connect to each point.

STEAM POINTS

The steam points are made of extra-heavy hydraulic steel pipe ¾ to 1 inch in outside diameter and 6 to 20 feet long. Lengths over 12 feet are now seldom used at the face, partly because the short points can be handled with greater ease and thaw the ground more evenly. There are many kinds of points, differing in the type of drivehead, steam connection, and form of the bit. The lighter points are fitted with a heavy T, with a tool-steel plug for a drivehead and a pipe nipple for the steam connections, but the standard point has a heavy tool-steel head with the nipple welded to it or fastened by special attachments. A hole is usually drilled through the solid head for inserting a small bar for turning the point while being driven.

The points may have either round-pointed, diamond-shaped, chisel, or cross bits, the kind used being governed by the character of the ground. The round-pointed or straight bit is most commonly used. With a small amount of steam turned on, the point is driven into the face, and where two men work together one drives with a heavy hammer while the other guides and rotates the point. In some ground thawing is rapid enough and other conditions are such that the point can be quickly advanced, although progress can not be faster than the gravel thaws ahead of the point, so that a number of points are generally under way at a time. Hard driving is commonly necessary, as the gravel ahead of the point must be pushed to one side or some of the larger rocks drilled through. When large rocks are encountered, it usually is advisable to pull and start a new hole.

When steam is used for driving the points, there is generally a "blowing back" or escape of steam, which fills the workings, rendering vision difficult and causing the gravel in the roof to thaw and slough. To overcome this, many miners use hot water instead of steam while driving. The water then used is pumped from the sump and is heated with steam from the exhaust of the pump. This method, however, requires additional piping and tends to wash and slough off the face so that it is subsequently more difficult to plug the hole around the point and seal in the steam.

SETTING POINTS

The points are set horizontally along the face, spaced 2 to 4 feet apart and at a horizon where they can be most easily driven, usually just on top of bedrock or a few inches below if bedrock is not hard or blocky. Irregularities of bedrock may, however, be such that the point may be in both gravel and bedrock. After the point has been driven home it may remain during the thaw, but it is more customary to withdraw the point and insert a "sweater." Sweaters are made of ordinary iron pipe 3/8 to 1/2 inch in diameter; the head is fitted with a **T** for steam connection and a plug for light driving. Their use allows a large saving in the cost of equipment, and as the points can not always be withdrawn after the thaw is completed these light pipes can be bent back and out of the way of the workers.

The collar of the hole is now carefully plugged by wrapping burlap or similar material around the point or sweater and ramming it tight, so that no steam will "blow back." The steam is then turned on; it is regulated with the valves at each point and as much of it is given as the ground will take. Regulation of steam requires experience, as some ground will take the full steam pressure whereas in other ground where the gravel is tight only a small amount can be used. While thawing is under way there is a constant shower of gravel from the roof, and the point man must be on a constant lookout for large falling rocks.

In easy ground two men can generally accomplish more working separately than working together. The rate of driving or setting the points varies according to the length of the point and the character of the gravel. In average ground two men working together can set ten to thirty 9-foot points per shift, while in some of the easy ground one man may set twenty to twenty-five 8-foot points. Where the gravel is tight and bowldery and bedrock is blocky, as at a number of mines in the Fairbanks district, it often requires the hard work of two men to set four to six 9-foot points in eight hours.

TIME NEEDED FOR THAWING

The time required to complete a thaw and the duty of a steam point are governed by numerous factors, chief among which are the character of the ground, distance between points, length of point, height of face, and steam pressure. In favorable gravel and under average operation the steam is turned on for 8 to 12 hours, while in tight gravel with much clay 45 hours may be required. Under average conditions 10 to 20 hours are necessary. After the steam is turned off the gravel retains heat for some time and thawing continues until the heat is dissipated. This "sweating" completes the thaw, but the gravel should not be excavated until several days have elapsed and the ground has cooled. The demand for thawed gravel at most mines is, however, so urgent that most of it is mined while still warm, often hot.

The steam point will normally thaw 1 to 3 feet beyond the end of the bit. The average area thawed with a 9-foot point is 30 to 45 square feet or 7 to 8 cubic yards. The amount of steam required per point, under average conditions, is generally considered to be 1 boiler-horsepower, although there are instances where 2 boiler-horsepower was required. High steam consumption is usually due to inefficiency and long, poorly insulated steam lines or to the character of the material thawed. Gibson[37] states that the horsepower per steam point at five operations at Nome ranged from 0.78 to 1.12; 25 to 90 points, averaging 7 feet in length, were set per thaw and, with steam turned on for 8 to 12 hours and "sweating" continuing one to two and one-half days, 2.28 to 7.11 cubic yards were thawed per point.

COSTS

Under favorable conditions, ground in drift mines has been thawed for 2 cents per square foot, or about 15 cents per cubic yard. Such low costs are, however, seldom attained, especially at the mines

[37] Gibson, A., "Drift mining in the frozen gravel at Cape Nome": Min. and Sci. Press, Mar. 7, 1914, p. 404.

operating at present. In the more difficult ground or at small mines the cost is often 10 to 12 cents per square foot, or about 50 to 75 cents per cubic yard. Under average conditions, 30 to 40 cents per cubic yard is about the usual figure. Ellis[38] estimated that steam thawing in the Fairbanks district accounted for about 20 per cent of the total cost of drift mining.

DRIVING POINTS UNDER DIFFICULT CONDITIONS

Where gravels are tightly packed or the bedrock is irregular, hard, and blocky, or overlain by heavy gravel, driving the points is slow and difficult. The use of machine drills for drilling holes in such ground for inserting the steam points or "sweaters" has proved successful at several drift mines. This method was also tried at other operations where, however, it was unsatisfactory mainly because the wrong type of drill and equipment was used.

THAWING ON LITTLE ELDORADO CREEK

The Idaho Mining Co., on Little Eldorado Creek in the Fairbanks district, has been very successful with this method, which has been the one factor that has determined profitable operation.

The deposit averages 165 feet in depth, and although it is solidly frozen the average gravel seldom contains more than about 5 per cent of ice. The gravel is tightly packed and of medium size but contains some large hard quartz and schist bowlders, which lie on the bedrock. The bedrock is a mica schist, soft beds alternating with harder slabby ones. Up to the time the present method was adopted, as later described, an average of 3½ feet of gravel and 1½ feet of the bedrock was mined. A 70-cubic foot air-brake locomotive compressor supplied the air and an old boiler served as an air receiver. This equipment was used to a good advantage, although better results could have been obtained with a larger compressor, for the pressure at the receiver dropped from 80 to 55 pounds and less when the drill was in operation.

A BCRW 430 jack-hammer drill, equipped with the water attachment by which a small amount of cold water is delivered under low pressure through the hollow ⅞-inch drill steel to the bit, was used for drilling and was easily handled by one man. This use of water instead of air or steam accounts mainly for the successful drilling. Drill steels were used in 3, 6, and 9 foot lengths and equipped with cross bits gauged from 1½ down to 1¼ inches. The holes were usually drilled 3 feet apart in a horizontal line just on top of bedrock

[38] Ellis, H. I., "Thawing methods at Fairbanks": Eng. and Min. Jour., July 3, 1915, pp. 1–6.

or a little above it in the gravel. Two boxes supporting a plank, placed at the proper inclination and at right angles to the face, supported and guided the drill. The hard bowlders were easily drilled through, although a new hole was generally started when an unusually large one was struck. A little caving or "raveling" of the holes at infrequent intervals caused slight binding of the drill, but this was attributed mainly to the low air pressure. Very little trouble was experienced in the freezing of the air, as water traps were used in the steam line and dry air was delivered to the drill.

Five 9-foot holes could ordinarily be drilled with a set of steel before resharpening was necessary. With the old method of setting points by hand it required eight hours for two men to set four to six 9-foot points, while with this method one man would average 180 feet of drilling, or 20 holes, insert the 3/8-inch sweaters, and get the thaw under way in eight hours. A 9-foot hole could usually be drilled in 20 minutes. It was estimated that the cost of drilling and setting the sweaters, which included the labor and mess cost for one man, 1/4 cord of wood for running the compressor, and wear and tear on the equipment, was $13 per shift, or 65 cents per 9-foot hole.

From 40 to 45 hours were required for thawing, as only a small amount of steam could be turned on. After the steam was turned off, the ground was sweated for about one day. Thawing usually extended 18 inches beyond the end of the sweater, although 40 square feet of area were sometimes thawed per sweater. The cost of thawing is not known but the entire cost of operation in 1922, exclusive of capital and royalty charges, was 74 cents per square foot for the 60,000 square feet mined.

NEW DRIFT-MINING METHOD OF IDAHO MINING CO.

A new method of drift mining involving modern underground practices has recently been installed and developed at this same property on Little Eldorado Creek, Fairbanks district, by J. F. Foran, the engineer and manager for the Idaho Mining Co. The frozen gravel and bedrock are drilled and blasted down and delivered to the cars by an underground scraper and successfully sluiced on the surface, dispensing with the customary steam-thawing methods.

New equipment for this purpose was installed after the new shaft, 238 feet of main drifts, and 30-foot station level had been completed by the earlier method. The present mechanical equipment includes three 50-horsepower boilers, a 7 by 10 double-cylinder hoist, a 6-wheelbarrow-load self-dumping bucket and carrier, a No. 5 Sturtevant blower for ventilation, a 650-cubic foot Leyner air compressor, an 8-inch centrifugal pump for pumping the water for sluicing, three BBRW 13 jack-hammer drills, one 6½-horsepower "Turbinair" double-drum air hoist, and one 12-cubic foot Quincy box-type bottomless slush scraper. The air drills are of the wet type, using $\frac{7}{8}$-inch hollow hexagonal steel with a cross bit of $1\frac{3}{8}$ inches gauge. Starters are seldom used, as the drilling is done with 5-foot steels.

The shaft is 169 feet deep to bedrock and is 6 feet in bedrock. It is 7 by 7 feet in size in the clear and is fully crib timbered down to the square-set station at the bottom. Moving and setting up the old plant, sinking, and timbering the shaft cost $2,500. The main drifts, continuing from where they stopped with the old method, were driven a total distance of 275 feet upstream and 240 feet downstream. Crosscuts 280 feet and 185 feet in total length were then driven at the respective ends of these drifts to the side limits of the pay. The $6\frac{1}{2}$ by 6 foot drifts were driven by one driller and two muckers working two faces, under the new system of drilling and blasting, at the rate of 7 feet per eight-hour shift, at a cost of $4.50 per foot. These drifts required no timbering, whereas those driven by the old method of thawing required three-piece sets and top lagging. The crosscuts at the ends were driven 18 feet wide and 5 feet high by two drillers and four muckers who worked two faces a shift, advancing each face an average of 4 feet. A block of ground containing about 120,000 bedrock square feet of pay was opened up.

SYSTEM OF MINING

Starting in the crosscuts at the extreme end of the block, mining proceeds along the wall nearest the shaft and advances toward the shaft. Two drills are used at the upstream end and the average height of face carried is $4\frac{1}{2}$ feet (2 feet of gravel and $2\frac{1}{2}$ feet of bedrock). The back holes are drilled in the gravel and spaced 3 feet apart, the cut or breast holes are drilled in bedrock and spaced $2\frac{1}{2}$ feet apart, and the lifters are drilled in bedrock with 3-foot spacing. The holes are all drilled 5 feet deep and break to the bottom. With two drills working, a 130-foot face can be drilled and the holes loaded and shot in two 8-hour shifts. One man will on an average drill 150 feet of hole, load, and shoot it; in other words, 100 square feet, about 17 cubic yards, are ordinarily drilled and broken per man per shift. One steel will usually drill an average of three 5-foot holes. There is never any trouble with stuck steel and practically no trouble with freezing of the drills.

The holes must be blown out with air shortly after drilling, to remove water and so prevent ice from forming and closing them. The holes are loaded with 40 per cent straight nitroglycerin dynamite, four and one-half sticks to the hole. No stemming is used. This powder has been found to be too fast for the gravel and too gassy for the ventilation provided. The average powder consumption has been 0.4 pound per bedrock square foot. The cost of the powder is 7½ cents and of fuse and caps 2½ cents, a total explosives cost of 10 cents per square foot, or about 60 cents per cubic yard.

From 12 to 24 hours after blasting, the material is scraped from along the faces to the main drift up a short incline and dumped into a car. The scraper is dragged back and forth by cables operated from the two-drum air hoist.

DELAYS

A great deal of trouble has been experienced and time lost through freezing of the air in the rotary gears of the air hoist. The incline up which the scraper is dragged has also caused some delay and must be taken down and set up at a new place for about each 1,300 square feet of bedrock scraped, requiring two to three hours each time. It is planned to put the main drifts 6 feet lower in the bedrock, which will dispense with the incline. Some delays are also occasioned in tramming, as the two trammers can not keep pace with the scraper when it is operating properly. Under the present arrangement the scraper averages running only about five hours out of the eight, although an average of about 250 square feet of bedrock is scraped during that period. With these difficulties corrected, so that almost continuous scraping is possible, and with three drills busy at the face, it is expected that about 350 square feet can be scraped per shift. As equipment is lacking, only one drill is operated at the downstream face, where the material is shoveled into wheelbarrows after it has been blasted down.

SAFETY MEASURES AND HAULAGE

The workings are kept safe by putting in bulkheads about every 25 feet along the face. These bulkheads are 4 by 8 foot timber cribs filled with waste gravel. With each advance of about 40 feet another row is put in. At intervening places where the roof may slab, as at the lower points, a post with cap is set. As the work advances these are removed and the ground is allowed to settle.

After the material has been scraped to the car it is trammed to the shaft, dumped into the bucket, hoisted to the surface, conveyed over the incline cable, and automatically dumped into the sluices.

REASONS FOR SUCCESS OF METHOD

The blasting down of frozen gravels in drift mines is not a new idea, but has been tried at numerous mines. It has not proved practical heretofore because of the character of the material which still required thawing after being broken. The success of such blasting methods at the placer on Little Eldorado Creek is due to the unusual character of the material mined. This deep, tightly packed frozen gravel contains an unusually small amount of ice, not more than about 5 per cent, which occurs as small crystals and to a lesser extent as small masses or seams. The shattering effect of the detonation is mainly responsible for preparing this material for sluicing without the necessity of the customary thawing. The heat liberated by the explosion plays but a comparatively small part. As this material strikes the water and passes through the sluices it readily disintegrates and is satisfactorily sluiced.

This mine now employs 15 men and operates but one shift of eight hours. The success of this method has been proved, although the operation must still be considered in the experimental stage. When once properly equipped and developed, so that two drills and a scraper can be kept busy at each face, the management believes that 1,000 to 1,400 square feet of bedrock can be mined per day of two shifts by working a crew of about 40 men, at a cost of 50 cents per square foot, exclusive of capital charges and royalty.

HYDRAULICKING

Frozen gravels in a drift mine have been hydraulicked on different occasions on a small scale. With one method the gravel face was nozzled down with water pumped from the underground sump, which was warmed by the steam exhaust of the pump. The water accomplished both the thawing and breaking down of the gravels. The excess water was drained to the sump to be reused, and the material broken down was shoveled or scraped into wheelbarrows or a car and conveyed to the surface for sluicing. The main difficulties encountered were that most of the bedrock had to be dug and cleaned by hand, and there was excessive wear on the pump lining.

At another operation in a low-lying bench, where the pay streak was composed of light gravel containing only a small amount of porous frost, water was conducted down the shaft and to the working faces through hose and pipe, and the gravel and bedrock were nozzled down and sluiced to the sluice boxes in the main crosscut. Diagonal paralleling drifts had been driven from the main crosscut. Hydraulicking started at the innermost faces and retreated toward the main crosscut, leaving narrow pillars between the drifts which were later removed. An adit on low grade, which by force of conditions could be made available for no other use, was employed for carrying off the water and the light material in the tailing. The main bulk of the tailing was hoisted to the surface by way of the shaft. The average height of the working face was 5 feet, and about 4,000 square feet of bedrock were so mined. Unless it may be in some bench deposit affording exceptionally favorable conditions for a method of this kind, underground hydraulicking in Alaska on anything but a very small scale presents many difficulties which greatly outweigh the advantages of the regulation methods of drift mining.

PRIMITIVE DRIFT-MINING METHODS

In the Circle (fig. 1, *37*), Fortymile (fig. 1, *41*), and some of the more isolated districts a number of miners work alone and with the most primitive methods take out a small dump each winter. A small shaft 12 to 25 feet deep is sunk in the frozen ground to bedrock, and an area of 500 to as much as 2,000 feet square is opened up. The frozen gravel is thawed with wood fires. Kindling is placed along the face, with a layer of dry wood on top, and the pile is built up to a height of about 2 feet. It is then covered with coarse gravel or stones or a layer of green wood with a sheet-iron plate over it. The placing and handling of these fires require experience, for the heat must be retained and held against the face, otherwise the roof will slough badly. Sometimes a number of fires are built. Such fires usually burn three to five hours and thaw 12 to 18 inches back into the face. They are generally ignited in the early evening, so that the thaw is complete by morning. Practice varies, for at one mine three piles of wood 8 feet long and 2 feet wide and high burned for 10 hours, after which the ground was "sweated" for 24 hours, thawing the face to an average depth of 16 inches (about 40 bedrock square feet).

Two shafts 50 to 75 feet apart are sometimes used, so that while gravel is being mined from one it is being thawed in the other. At one place a 60-foot adit was driven on a bench deposit to the edge of the pay and a 25-foot raise made to the surface for ventilation. Drifts were then driven a short distance up and down stream and the gravel removed by working toward the portal of the adit. The working face was 2 to 4 feet high. This lone miner mines an average of 1,000 wheelbarrow loads of gravel each winter, which return $200 to $400 in gold when sluiced the following spring.

COSTS

Present conditions for drift mining in frozen gravels are seldom conducive to low costs, mainly because the ground remaining is less favorable and the smaller areas limit the scale of the operations. When drift mining was at its height, frozen gravels were drift-mined at several mines in the Fairbanks district for as low as 40 cents per square foot, and in a few mines near Nome costs of 25 cents per square foot were reported. In 1915 Ellis[39] estimated that the cost of drift mining in the Fairbanks district was 50 cents to

[39] Ellis, H. I., "Winter drift mining at Fairbanks": Eng. and Min. Jour., Oct. 30, 1915, p. 710.

$1.25 per square foot of bedrock, the average being 75 cents. He based his estimate on the duty of the shovelers, which was taken at 30 to 35 square feet of bedrock per 10 hours, or equivalent to about 7 cubic yards of gravel in place.

Present costs in the Fairbanks district are 60 cents to $1 per square foot, with several mines where the cost is higher. The average, however, is about 75 cents. Drift mining in the Tolovana district costs 50 to 75 cents per square foot, with 32 cents reported from one operation where the gravel was light and all conditions favorable. In the Ruby district, where the pay channels are rarely more than 75 feet wide and conditions are generally adverse to cheap mining, the operating costs at six mines ranged in 1922 from 60 cents at the more favorable operations to $1.25 where they were adverse, averaging 85 cents per square foot, or about $5 per cubic yard. The average cost of steam thawing here was 45 cents per cubic yard and 35 cents for sluicing.

In 1914 Gibson [40] reported the operating cost per cubic yard, exclusive of preparatory work, at five operations at Nome as follows: Thawing, 27 to 50 cents; mining, 94 cents to $1.28; sluicing, 9 to 64 cents; total operating cost, $1.40 to $2.41. The total height of the working faces was 4 to 5 feet, 16 to 30 men were employed, and 80 to 158 cubic yards of pay gravel were hoisted at shafts 45 to 81 feet deep per day of two 10-hour shifts. Drift mining at Nome is now virtually obsolete, for most of the remaining ground is unfavorable for profitable operation. Lumber for timbering and fuel oil for steam generation are used there, and most of the available ground has been acquired by dredging or hydraulic mining interests.

HYDRAULIC MINING

Hydraulic mining, as interpreted in this report, comprises breaking down the face by water under pressure, washing the material into the sluices, sluicing the material, and disposing of the tailing. In order to assist in transportation and sluicing, an additional supply of water, known as ground-sluice, by-wash, or bank head water, is usually required. The most important requirements for hydraulic mining are an ample, continuous, cheap supply of water under high pressure, enough bedrock grade for the sluices, and adequate dump room for the tailing.

Hydraulic mining in Alaska is being conducted in creek deposits or in bench deposits, many of which are only slightly above creek level, so that adequate grades are generally lacking. The creek deposits are a few feet to 25 feet deep, whereas benches of similar

[40] Gibson, A., "Drift mining in the frozen gravel at Cape Nome": Min. and Sci. Press, Mar. 7, 1914, p. 404.

thickness are often overlain by barren overburden, forming a total depth of 40 to 50 feet. Although the bench deposits in Alaska do not have the great thickness or extent of some of those in California, there are in southern Alaska and the Upper Yukon country some auriferous benches as deep as 100 feet, mostly gravel, but usually unfavorably situated for hydraulicking. As a general rule in Alaska placers the gold is found close to bedrock, and if the pay gravel is overlain by great depths of barren gravel hydraulicking is profitable only when other conditions are unusually favorable. Most of the hydraulic mining in Alaska is therefore confined principally to the shallower or more favorably located placers. In hydraulicking shallow placers frequent moving of the giants and sluices is necessary, causing loss of valuable time when the water supply may be at its best. The presence of some bowlders is not so serious as in other methods of mining, but large quantities may prohibit mining. At many hydraulic mines in southern Alaska the exceptionally large quantities of bowlders counteract some advantages that mines in this part of Alaska may have over the hydraulic mines in some interior districts and on Seward Peninsula.

Soft, even bedrock which can be readily cleaned with the giant is one of the requirements for low-cost operation. Although the bedrock at many mines is favorable for hydraulicking, at other mines the bedrock is hard, blocky, and interbedded with softer rock or cut by numerous dikes. Much of this irregular bedrock surface can be cleaned with giants, nozzles, or small canvas hose and nozzles, but unless this is properly done the gold may be driven into pockets and crevices in the bedrock; then final cleaning by hand is generally necessary. Stiff clay, if present, is difficult to break down with the nozzle and may require blasting. A sticky clay is the most difficult to wash, although it can generally be well disintegrated by the giants before it goes into the sluices. Cemented gravels occur rarely in Alaska.

WATER SUPPLY

STREAM GRADES

The average fall of most of the streams in Alaska on which placer deposits are found is slight, except in some relatively small districts in southern Alaska. These stream grades in the Seward Peninsula and the interior districts usually range from 25 to 150 feet per mile but in southern Alaska are generally 100 to 200 or more feet. Local irregularities in bedrock may provide steeper grades than the average, and the tributaries and the upper reaches of the main streams are generally steeper. A grade of 6 inches to 12 feet, or 220 feet per mile, is considered the minimum over which gravel can be economically moved through the sluice boxes without an excess of water. The hydraulicking of stream beds or flat-lying benches also requires a plentiful supply of ground-sluice or by-wash water, and a special method for obtaining a better sluice grade may be necessary. Also, the lack of natural dumping facilities generally necessitates stacking the tailing.

GROUND SLUICE OR BY-WASH

The ground-sluice or by-wash water flows over the bank or to the sluices through open channels and is generally the surplus creek water left after the giants have been supplied. The amount required is governed principally by the grade of bedrock, the character of the material, and the size of the sluices. The quantity available for this purpose is usually small during most of the working season, and it is customary to use the greater part or all that is available. At some of the operations one to three times the quantity supplied by the field giants may be used. The largest hydraulicking operations in southern Alaska use 1,000 to 2,000 miner's inches of ground-sluice water.

CONDITIONS GOVERNING WATER SUPPLY

The conditions governing the water supply for hydraulic mining and the construction of dams, water conduits, and pipe lines have been discussed under "Water supply." In general, large supplies at high heads are only available at certain operations in southern Alaska; favorable conditions are also found on the Seward Peninsula but require long, expensive ditch lines. Fluctuations in the flow are pronounced, especially in the interior districts, where the water supply is generally small and under low head. Favorable reservoir sites for impounding large quantities of water are rare, so that virtually all operations are handicapped by reduced water supply during part of the season. Many have to stop hydraulicking entirely during low-water periods, while others continue only at greatly reduced capacity. Mining in the interior districts is especially characterized by the use of small quantities of water which have been impounded and are released intermittently for short periods. The water supply also quickly diminishes when the temperature drops to freezing.

Hydraulicking of the gravels usually does not start until early in June or continue after the first heavy freeze late in September. Most preparatory work is done in April and May or after mining is halted in the fall. The working season is about 90 to 120 days, but in high elevations where snow water must often be relied upon may not be over 30 days. Many hydraulicking operations benefit by only a small part of this short season. Disregarding any time lost from lack of water, the time of active hydraulicking at most mines amounts to only 40 to 60 per cent of the available season, the balance of the time being spent in moving, setting up, cleaning up, and other jobs. Where only one shift is worked, less than a quarter of the time may be spent in moving gravel.

Most hydraulic mines in Alaska are small, for those requiring comparatively small investments and employing only two to eight men are best able to meet average conditions. Many small operations have 50 to 500 miner's inches of water available under heads of 35 to 200 feet, and in an average season will mine 2,000 to 30,000 cubic yards of gravel. The larger mines, most of which are situated on the Seward Peninsula and in southern Alaska, have 500 to 2,500 miner's inches of water under heads of 100 to 300 feet and mine 30,000 to 100,000 cubic yards in an average season. This maximum represents less than 1,000 cubic yards daily and is rarely exceeded, except at some mines that figure only the time of actual hydraulicking.

CAPITAL INVESTED IN HYDRAULIC OPERATIONS

The amount of capital invested in water supply, hydraulicking equipment, and development work varies widely because of the many differing conditions. The cost of delivering water under pressure head to the property is often the main item. As previously mentioned, some operators use conduits constructed by former operators and some have been able to obtain used hydraulic equipment at nominal cost. Many small mines operating under low head and with small outfits have been equipped with pipe, giants, etc., at a cost of $1,000 to $3,500. Some hydraulic mines operating under average conditions and handling between 250 to about 750 cubic yards of gravel were equipped for $3,500 to $15,000, and larger plants have cost as much as $100,000. Within these limits the cost of the dam, ditch line, etc., may be included, except where the ditches are of large capacity and great length. There are numerous instances where from one-quarter to one million dollars, and occasionally more, has been spent in water supply, equipment, and opening up the property, so handicapping operation that profitable results were impossible.

IMPORTANCE OF HYDRAULIC MINING

The life of the average Alaska hydraulic mine on creek or shallow bench ground is governed by many conditions, but usually is 5 to 10 years. A few hydraulic mines have been active for much longer periods, while others are operated periodically by leasers or through changes in ownership.

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In spite of the many adverse conditions cited hydraulicking has an important place in Alaska placer mining. At most mines where this method is used it can generally be applied better than any other method. However, numerous creek placers being hydraulicked or worked by other methods make a production each season that is ridiculously small, especially when the investment in a water supply and equipment is considered. Conditions at some such properties favored dredging, by which method the ground could have been worked out in easily one-fifth the time at a much lower cost and no doubt with better recovery of gold.

DUTY OF WATER

DEFINITION

The duty of water in hydraulic mining is usually stated as the number of cubic yards of material which can be broken down and put through the sluices by 1 miner's inch (1½ cubic feet per minute) in 24 hours. It varies with the depth and character of the material, the character and grade of bedrock, the size and grade of the sluices, the type of riffles, the quantity and pressure of the water, the facilities for disposal of tailing, and the skill of the operator. The duty of water must be at least approximately known before estimates can be made as to the possible scale of operation, and a properly balanced plant can be installed. It is also a most important factor in determining the efficiency of the operation. Unfortunately very few Alaska operators measure the amount of water used or keep account of the time during which the water is turned on, consequently complete or accurate data are seldom available.

DATA ON DUTY OF MINER'S INCH

The table on the duty of the miner's inch in Alaska includes data from engineers whose aid is acknowledged and estimates based on the data obtained from the operators. As stated, some of this latter information was incomplete, but where possible the missing data were closely calculated and the approximate duty of the water derived. These estimates are given mainly to show the generally low duty obtained.

Duty of miner's inch

Locality	Height of bank, feet	Sluices: Width, inches	Sluices: Depth, inches	Sluices: Grade, inches	Riffle	Head on field giants, feet	Water, miner's inches	Duty, cubic yards in 24 hours	Remarks
Seward Peninsula:									
Anvil Creek [a]	30	33	18	4½	Angle iron	----	500	1.4	Heavy, partly frozen gravel, much flat schist.
	4½	----	----	----	----	----	100	3.0	Frozen-muck stripping; 3-inch grade; ditch head water.
	20	----	----	----	----	----	400	10.0	Frozen-muck stripping; 4½-inch grade.
	30	30	24	3–5	Blocks	150	543	2.63	Unfrozen, coarse, subangular gravel; hydraulic elevator.
Boulder Creek	15	30	30	4	Mn grate	90	[b] 700	1.00	Unfrozen medium gravel, much flat schist.[c]
Big Hurrah Creek	6	36	18	5	Rails	----	[b] 900	1.20	Unfrozen medium gravel, much flat slate.[c]
Little Creek	15–35	48	24	5–7	Angle iron and rails.	300	----	1.25–1.5	Partly frozen medium gravel; hydraulic elevator.
Osborne Creek	9	36	24	7	Blocks, rails	170	750	1.2	Partly frozen heavy gravel; hydraulic elevator.
	2½	----	----	----	----	160	600	3.4	Stripping moss and muck with giant.
Ophir Creek	9	----	----	5	Blocks, rails	----	----	1.1–1.35	Partly frozen medium gravel; hydraulic elevator.
Mount McKinley district: Moore Creek.	10	24	20	6	([d]) and ([e])	----	[b] 300	1.6	Unfrozen medium round gravel; tailing stacked two hours a day.
Fairbanks district:									
Pedro Creek	15	36	30	11	Blocks	----	[b] 350	1.2	Partly frozen, heavy gravel.[c]
	6	36	30	5	Rails	130	[b] 400	.8	Partly frozen medium gravel.[c]
Goldsteam Creek	8	----	----	----	----	----	200	3.5	Stripping muck with pumped water, 3 per cent grade.
Circle district:									
Mastodon Creek	10	30	24	8	Blocks	100	[b] 500	.7	Partly frozen round medium gravel.[c]
([f])	12	30	----	----	do	100	240	2.5	Partly frozen gravel; 20-hour inch.[c]
Seventymile district: Crooked Creek.	7	30	24	8	do	60	[b] 460	1.2	Partly frozen light gravel.[c]
Yentna district:									
Falls Creek	9	36	30	8	([e])	100	[b] 500	.9	Unfrozen medium gravel; bowlders.[c]
Nugget Creek	6	28	24	7	([e])	200	[b] 450	.8	Do.
Peters Creek	9	30	24	6	Rails[e]	185	[b] 800	.8	Do.
Kenai region: Crow Creek.	10	52	36	6	Rails	145	[b] 2,600	.5	Very coarse wash; many large bowlders; much ground-sluice water used.[c]
Nizina district:									
Dan Creek	10–18	48	44	5	do	275	----	.25–.4	Unusually coarse wash and many bowlders; much ground-sluice water.[c]
Chititu Creek	10	40	36	5½–6	do	250	[b] 2,200	.35–.5	Heavy gravel, many bowlders; much ground-sluice water.[c]

[a] Purington, C. W.
[b] Includes ground-sluice water.
[c] Stack tailing with a giant.
[d] Punched plate over matting.
[e] Longitudinal steel-shod riffles.
[f] Ellis, H. I.

They can, however, be considered as being close approximations, although the duty at each operation is subject to variation, and many of the examples are based on data covering short periods only. As given in the table, the number of miner's inches of water used includes the average amount used by the field giants, the stacker giant, or the elevator, as the case may be, and where so noted includes ground-sluice water, which is the most variable in quantity. At most operations the water pressure decreases rapidly as the work proceeds upstream.

REASONS FOR LOW DUTY

The generally low duty is accounted for mainly by the low bedrock and sluice-box grades, by the general low water pressures, and by the large amount of water used by the elevator, or that used by the stacker giant, or the large amount of ground-sluice water, as the case may be. At some Nome operations much of the material is flat, while in the southern Alaska districts the gravels are unusually heavy, and large amounts of ground-sluice water are generally required. Frozen ground at some mines may lower the duty materially, whereas at others the giants can pipe down the material as fast as it can be transported to and through the sluice boxes. Data are unfortunately meager on operations where it is unnecessary either to elevate the material or to stack the tailings. Under such conditions a duty of 3 to 4 cubic yards should not be uncommon. Tables on giants, published by manufacturers, usually show that the duty of a giant under average conditions is taken as approximately 3 cubic yards. In hydraulicking the small rounded gravels of the "White Channel" bench in the Dawson country the water duty ranged from 2 to 10 cubic yards, with sluice grades of 12 to 14 inches.[41] The duty at the Yukon Gold Co.'s operations on Bonanza Creek ranged from 4.50 to 6.60 cubic yards.

Water under high pressure is more effective than under low pressure, and the duty of the water is apt to be low when the head is less than 200 feet. Purington [42] contends that an increase in head will not increase the amount of gravel which can be moved to the sluices, for the force of the stream from the giant is entirely expended in piping (that is, directing the stream from the nozzle) against the face, while the grade of the sluice is the governing factor in moving the gravel after it leaves the face. Although it is true that a given quantity of such spent water will only move a certain amount of gravel to and through the sluices, being dependent on the grade over which it runs, a high head delivers more water and

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[41] Purington, C. W., Methods and Costs of Gravel and Placer Mining in Alaska: U. S. Geol. Survey Bull. 263, 1905, p. 139.

[42] Purington, C. W., Work cited, p. 134.

will more readily disintegrate the material than a lower one if other conditions are equal. It is also standard Alaska practice to get behind the material and drive it into the cut and to the sluices, where a high head will move it more readily and farther, thereby permitting the working of larger pits and requiring less frequent moves of the giants.

HYDRAULIC MINING METHODS FOR BENCH AND CREEK DEPOSITS

The various conditions that govern hydraulic mining have brought about the development and adoption of different methods. Although these may follow the same general principles, there are different ways of piping down the material, of delivering it to the sluices, and of disposing of bowlders and tailing. The methods used for removing moss, muck, and in some places barren sand, gravel, and other overburden before the hydraulicking of pay gravel have been described under "Stripping overburden."

The hydraulicking of bench deposits at elevations well above stream level is comparatively simple when a fair water supply is available, as the grade for sluicing and room for gravity stacking of tailing are usually adequate. If the deposit is thick, hydraulicking may be started at the rim or the exposed face, or a deep cut may be sluiced out until pay gravel is exposed. An adit may be driven in the bedrock and a raise extended to the surface, to be enlarged by piping the surrounding material into it, thus opening a pit. This practice was followed in opening a lake-bed deposit in the Silver Bow Basin near Juneau (fig. 1, *55*), where a long tunnel was driven through solid rock to the deposit. Similar means have been used in opening some of the high-bench gravels in California and elsewhere.

The sluice boxes are placed in the tunnel or in the cut, as the case may be. The giants are set up at a safe distance from the bank, which is then undercut and broken down by the stream from the giants. The loosened material is transported through short sluices in the bedrock to the main sluice or sluice boxes. These bedrock sluices are kept close to the face, and if the ground is hard or irregular may be an item of considerable expense. Steel flumes or chutes are sometimes laid on bedrock to assist in moving the loose material to the sluices, but the usual procedure is to carry the nozzles behind the broken-down material and drive it into the head of the boxes. To permit continuous operation two or more working faces should be carried. An oblique stream from the nozzle will break down more gravel than one pounding directly against the face.

For undercutting, small nozzles are generally more efficient than large ones. In frozen ground undercutting is slow and unsatisfactory, as a frozen bank is not only difficult to cave but the caved material usually breaks off in large masses. Constant playing of water under pressure against a frozen face is poor practice. Better results can generally be obtained by letting bank head water aided by the giants cut deep vertical channels in the bank, thus exposing a large area to thawing, and then piping off the thawed material from time to time.

Where shallower placers are hydraulicked, the giants are generally set on top of the bank. By this method advantage is taken of the grade, and the material as loosened is driven ahead into the pit and the sluices. Moreover, in frozen ground a large surface can be exposed for thawing.

Before a creek deposit is mined ample provision must be made for diverting the creek water and all excess water around the workings, as stated under "Water supply," and special provision made for safeguarding the mine from flood water.

GENERAL HYDRAULIC MINING METHODS

Hydraulic mining as practiced in Alaska, excluding the bench methods mentioned or the use of hydraulic elevators, can be divided into three general methods: (1) Piping the material into the head of the boxes; (2) piping the material over the side of the boxes; and (3) a combination of 1 and 2.

Methods 2 and 3 are special methods that have been developed to meet certain adverse and limiting conditions encountered in mining the creek placers and are also applicable to some bench placers. Method 2 can be divided into three general classes based on the position of the sluice boxes in relation to the surface of the bedrock, as follows: (*a*) The sluice boxes are all set in bedrock, with the tops below the surface; (*b*) the lower boxes are in or on bedrock and the upper ones on or above bedrock surface; (*c*) some or all of the boxes are on or elevated above bedrock.

The best method for any mine depends on many limiting factors, and each method has certain advantages.

PIPING INTO THE HEAD OF THE BOXES

The method of piping into the head of the boxes is the one most generally used at hydraulic mines in Alaska. It is best adapted for hydraulicking shallow benches and comparatively narrow creek deposits where the bedrock gradient is 6 or more inches in 12 feet. Its application in connection with mining deep benches has already been mentioned. One major advantage of this method is that all of the water used is devoted to sluicing, so that a comparatively small flow will often suffice. Mines having small or intermittent water supplies therefore find the method practical. The relatively short string of sluice boxes can usually be set at a steeper grade than that of the bedrock by taking advantage of irregularities in the bedrock surface or by cutting to the required grade. The light sluice boxes used can generally be installed quickly, which is a big advantage where small pits not over 6 or 8 feet deep necessitate frequent moving and setting up.

SLUICE BOXES

The sluice boxes are first placed on or in bedrock at about the middle of the lower end of the proposed pit, with the head box low enough in bedrock to permit proper entry. Where the bedrock is hard and the natural gradient is low, three or four boxes are generally used, but under favorable conditions there may be 12 or more. Timber or board wings at the head of the boxes, one on each side, direct the water and material into the head of the boxes. As a rule,

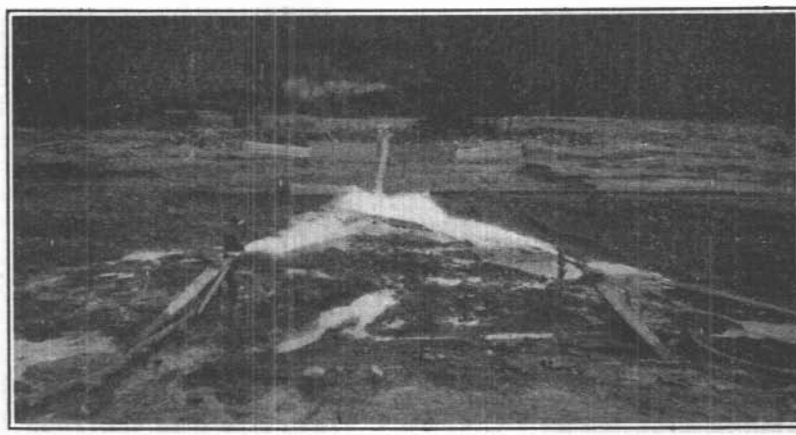


FIGURE 38.—Hydraulic mining. Piping into the head; sluice-box extension. Note the hose and nozzles

the field giants are set on top of the bank at a distance upstream from the wings that depends on the pressure. If only one giant is used, it is placed at the upper end in line with the sluices or shifted about as required; if two are used, one is placed near each upper corner of the proposed pit. The material is then piped into the head of the boxes.

Where the water pressure and other conditions are favorable, pits 300 to 450 feet long have been mined by the above method. However, in pits of this size intermediate or "booster" giants are used, and the material is moved in stages. Where the slope is satisfactory, a number of short pits can be mined by extending the sluices upstream after each pit has been piped in; but the advantage of this practice may be small if tailing must be stacked. Figure 38 illustrates such an operation on a shallow bench in the Hot Springs district (fig. 1, *30*).

As much more material can be moved through a sluice box than through the ground sluice or bedrock sluice, the giants should not be placed too far from the head of the boxes or the duty of the water will be greatly reduced. At those mines where the head of the boxes is placed above bedrock the material must be piped up a slope before entering the boxes, and the water backs up in the pit. With average bedrock conditions, a sump or pothole is almost certain to develop ahead of the boxes. This impedes the flow of water and material, and requires additional piping to move them into the boxes.

PLACER ON FALLS CREEK

A typical placer of this kind is on Falls Creek in the Yentna district (fig. 1, *26*). The creek deposit averages 8 feet in depth and

FIGURE 39.—Hydraulic mining in Yentna district. Piping into the head

is unfrozen rounded gravel with 10 to 15 per cent of bowlders, the largest being about 3 feet in maximum dimension. The bedrock formation is clay, shale, and sandstone, easily cleaned with the giants. The average pit mined is 80 feet wide and 125 feet long. Two field giants with 3-inch nozzles, working under a 100-foot head, are set on top of the bank, so that while one giant is piping gravel into the head of the boxes on one side of the pit the bowlders are being removed from the other side and piled by hand on cleaned bedrock. On account of the grade of bedrock 42 to 54 feet of boxes are all that can generally be installed. The sluice boxes are 36 inches wide and 30 inches deep, set on an 8-inch grade, and provided with steel-shod, 2 by 4 inch riffles placed lengthwise. The tailing requires constant stacking by a giant with 3-inch nozzle.

Figure 39 shows the general arrangement of the pit and the sluices, the method of removing bowlders, and the stacker giant at work. The water supply, including ground-sluice water, varies from 300 to 700 miner's inches. The average crew of eight men is divided into two 10-hour shifts. During periods of maximum water supply an area of about 1,000 square feet can be mined in two shifts or an average pit completed in eight to nine days. A set-up for a new pit is made in one day.

During one of the most favorable seasons 70,000 square feet of ground averaging 9 feet in depth (including 1 foot of bedrock) were mined in 73 days at a cost of 7½ cents per square foot, or 23 cents per cubic yard. Average costs are 30 to 35 cents per cubic yard. About $5,000 is invested in the 1,600-foot ditch and the hydraulic equipment.

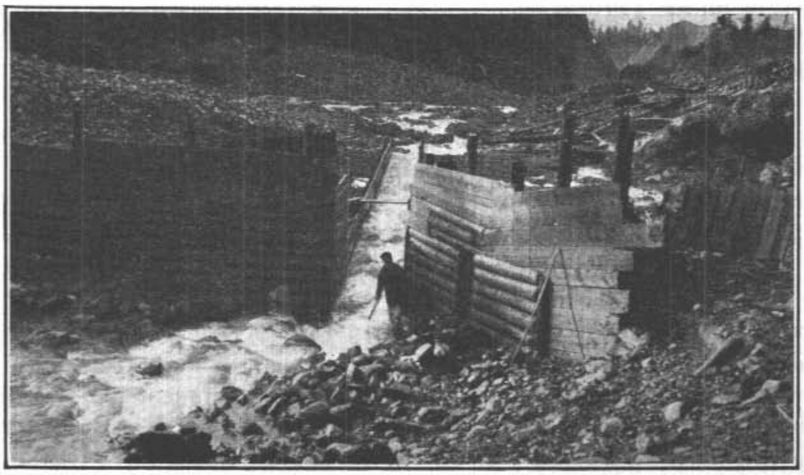


FIGURE 40.—Hydraulic mining at Crow Creek. Wings and sluices

HYDRAULIC MINE AT CROW CREEK

A large hydraulic mine on Crow Creek in the Girdwood district (fig. 1, *49*) is working an unfrozen creek deposit 6 to 25 feet deep, averaging 12 feet. The gravel is unusually coarse, about 50 per cent being bowlders 6 inches or more in diameter, many of them large. Mining is usually carried to a false bedrock of tough clay; the true bedrock is slate and graywacke, all readily cleaned with the giants.

The usual practice here has been to mine simultaneously two parallel adjoining pits. Each pit is 100 to 150 feet wide and 400 to 450 feet long, is worked separately, and has its own sluice boxes. The pits are kept abreast of each other and are alternately used as a by-pass for the creek water, the giants being at work in one pit while the bowlders are being handled in the other, so that mining is virtually continuous.

A No. 7 giant with 6-inch nozzle, working under a 145-foot head, is set on top of the bank of each pit, and sometimes another giant of similar size is set midway between them. The gravel from each pit is then piped into the head of the boxes, which are provided with heavy timber wings (see fig. 40). As the giants are moved upstream and the distance to the head of the sluices exceeds their working range, a smaller "booster" giant is set on bedrock at one side of the pit and about halfway down and drives the gravel into the head box. After the gravel in both pits has been piped in, the bank between the pits is removed and the bedrock is cleaned with the giants. The bowlders are drilled with air drills and blasted and put through the sluices with the rest of the material. A No. 7 giant with 5-inch nozzle under 170-foot head stacks the tailings from both sluices. The disposal of bowlders and tailing will be more fully described under those headings.

The sluice boxes are 5 feet wide and 3 feet deep and are set on a 6-inch grade; 8 to 10 lengths of boxes are generally provided for each line. Riffles of 40-pound rails set transversely are used in the first two boxes; the rest are 25-pound rails set lengthwise. In addition to the giant water, 1,000 to 1,400 miner's inches of ground-sluice water pass through the boxes. Including water for stacking the tailing, about 2,600 miner's inches are normally used, giving a water duty of about ½ cubic yard. In 1923, 66,000 cubic yards were mined, and the crew numbered 12 to 18 men. The cost of mining, exclusive of royalty paid for the use of the equipment and for the claims, was 43 cents per cubic yard. This property was equipped and opened over 15 years ago at an expense of about $250,000. Present equipment in use and the 1¼-mile ditch line would cost about $30,000 to replace.

PIPING OVER SIDE OF SLUICE BOXES WHEN BOXES ARE SET IN BEDROCK WITH TOPS BELOW SURFACE

The method of piping material over the side of sluices boxes set below bedrock surface is used in the Nizina district (fig. 1, *47*) for the hydraulic mining of creek deposits and is especially well adapted for the conditions encountered there. The gravel is piped over the side in two ways—by starting at the upper end of the new pit and working downstream or by starting at the lower end and working upstream. Each has its merits, which can best be shown in the description of the operations where they are employed.

HYDRAULIC MINING ON DAN CREEK

The Dan Creek Mining Co. on Dan Creek has one of the largest hydraulic mines in Alaska. The creek deposit mined is 6 to 18 feet in depth. The gravel is rounded but unusually coarse, containing up to 75 per cent of material over 8 inches in diameter, some bowlders being 6 to 10 feet in maximum dimension. The bedrock is slate of varying character and hardness, cut by occasional hard porphyry dikes which form high ridges, but in general is not hard and the average contour is quite regular. The gold is coarse and mostly nuggets of the " pumpkin-seed " variety; from 40 to 60 per cent will remain on a ¼-inch screen. Large quantities of copper nuggets and some native silver are also present.

Arrangement of sluices.—The pits mined usually range from 500 to 700 feet in length and 175 to 300 feet in width. After a pit has been completed a line of sluice boxes 4 feet wide and paved with longitudinal rail riffles is set in the upper end of the old rock sluice, just at the lower end of the projected pit. Usually 16 to 20 boxes are installed, but never less than 8, depending on tailing requirements. Short wings are constructed at the head of the boxes, and as soon as the water begins to run in the spring a central sluice running the full length of the proposed pit is cut through the gravel and into bedrock by means of a giant with a 4-inch nozzle. The bedrock sluice is made about 6 feet wide and 5 to 6 feet deep, or so deep that the tops of the boxes will be 1 or 2 feet below the surface of bedrock. The bottom is leveled with picks, with as little blasting as possible. The maximum grade obtainable ranges from 5 to 5½ inches, although grades as low as 3½ inches have been used.

Sluice boxes 48 inches wide and 46½ inches deep, inside dimensions, are then installed for the entire length of the bedrock sluice, connecting with the lower boxes. They are equipped with 20-pound rail riffles spaced at 4-inch centers, placed lengthwise, and spiked to 6 by 6 inch ties. The sides of the boxes are lined with 1½-inch boards, and the outside is protected by nailing heavy slabs or old boards along the upper parts.

Mining method.—The general set-up and arrangement of the workings are shown in Figure 41. A large amount of ground-sluice water is turned into the head of the sluices, generally about twice as much as that supplied by a field giant, so that the boxes run virtually full when a field giant is operating. The initial cut is first made to bedrock at the upper end of the pit, then two No. 4 giants with 5-inch nozzles worked with a head of 275 feet are placed on bedrock, one on either side of the sluice and well to the outer edge, as shown in the figure. While the giant on one side is piping the material along the diagonal face and over the side into the sluices the bowlder crew is working on the other side. The method of bowlder disposal is described later. (See "Bowlder disposal.") Thus sluicing and bowlder work alternate from one side of the sluice to the other. As a rule, two to three periods of each are required before bedrock is reached.

All the material except the largest bowlders goes through the boxes. These are undercut, rolled over, and left there on cleaned bedrock. A slice or cut 35 to 50 feet deep is made along the diagonal face to bedrock and 1 to 2 feet of bedrock are piped off, then the giant is moved ahead (downstream) to its next position. Two outfits of 2½-inch hose equipped with fire nozzles are used for the final cleaning of bedrock. Deep holes are cleaned with a siphon. The method involves piping over the side a series of diagonal cuts until the pit is completed. Continuous stacking of the tailing is done by a No. 4 giant with a 4-inch nozzle under a 310-foot head.

Clean-up.—The upper boxes and rock sluice are sometimes "cleaned up" as the work advances in order to safeguard against theft or flood, but generally the entire pit is completed before the clean-up starts. The clean-up is made only on day shift by a well-

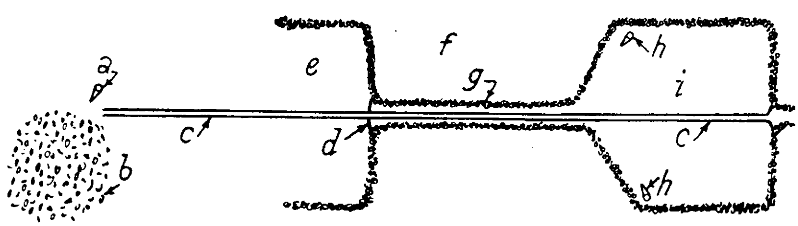


FIGURE 41.—Plan showing method of piping over the side of boxes, advancing downstream: *a*, Stacker giant; *b*, tailing pite; *c*, sluice boxes; *d*, wings; *e*, worked ground; *f*, unworked ground; *g*, bedrock cut; *h*, giant; *i*, pit about 200 feet wide

organized crew of 10 men. Ten boxes are generally cleaned and removed at a time. With the water cut down to the proper point, the rails from the upper or first 10 boxes are removed, the heavier material and the coarse copper nuggets are forked out, and the balance is worked down the sluice and cleaned up. The timber guards and the sides of the boxes, except the lower board, are then removed and with the canvas-hose outfits, one on each side of the sluice, the material alongside is piped in and another clean-up made. The remaining parts of the boxes are then removed and the material in the sluice is hosed down as clean as possible to the boxes below. The next 10 boxes are similarly handled, and after the entire sluice has been cleaned (75 to 80 feet are usually finished in a day) a final clean-up of the rock sluice is made by the foreman and four men who pick out the crevices and with a water siphon put all the material through two lengths of 12-inch riffled boxes which are placed across the rock sluice and moved along as the work proceeds. This final clean-up requires five to six days under average conditions.

FIGURE 42.—Hydraulic mining on Dan Creek. Completed pit showing bedrock sluice and removal of the boxes

Figures 42 and 43 show the completed pit with the clean-up under way.

Labor.—About 18 men are generally employed, the regular pit crew for each shift of 10 hours consisting of a foreman, nozzle man,

FIGURE 43.—Removing and cleaning up the sluices, Dan Creek

stacker man, sluice tender, powder man, powder man's helper, and two or three extra helpers, with the shifts so arranged that hydraulicking is practically continuous.

Water duty.—According to the manager, G. Howard Birch, the water duty per miner's inch averages 0.25 cubic yard and depends more on the volume of water used than on the pressure. This low duty is accounted for mainly by the unusually heavy material and the low gradient requiring large quantities of ground-sluice water.

Work accomplished.—Two pits were completed in 1923, which was an exceptionally favorable season for hydraulicking. No. 1 pit was 528 feet long and averaged 165 feet wide; No. 2 pit was 480 feet long and averaged 170 feet wide. The No. 2 pit, which averaged only 6 feet in depth, required 9 days for making the set-up, 17½ days for hydraulicking, and 10 days for the clean-up. For both pits 22 days were taken to make the set-ups, forty-two 24-hour days for hydraulicking, and twenty-six 10-hour shifts for the clean-up. The expenses for the season were $34,124. About $100,000 has been invested in the water supply and equipment.

Costs.—The entire operation is conducted in a most systematic and businesslike manner, and the mine is one of the few hydraulic mines where accurate, detailed accounts are kept of the operating data and the costs. These are summarized in the following table:

Hydraulic mining costs, Dan Creek Mining Co.

	1916–1920 average [a]	1921	1922
Costs per cubic yard:			
Operation	$0.091	$0.141	$0.081
Deadwork	.087	.159	.104
Explosives only	.054	.108	.046
	.232	.408	.231
Overhead, etc	.103	.242	.102
Total	.335	.650	.333
Operating data:			
Average depth, feet	23.4	12	18
Bedrock mined, square feet	131,294	140,218	154,786
Material mined, cubic yards	113,843	62,318	103,190
Actual 24-hour days operated	94.2	64	77.1
Average number of men employed	18.4	17.5	16.8
Average wage per shift, mess included	$6.04	$6.57	$6.39
Mess cost per man-day	$1.43	$1.68	$1.62

[a] Average per season over a period of five years, during which time 569,214 cubic yards of material were mined, at a total cost of 19 to 60 cents per cubic yard.

NOTE.—The above data include a small yardage mined on the benches.

HYDRAULIC MINING ON CHITITU CREEK

A similar method that differs in the disposal of bowlders and the construction of the sluice boxes is used at the No. 1 mine of John E. Andrus on Chititu Creek in the Nizina district (fig. 1, *47*), shown in Figure 44.

Set-up at No. 9 mine.—At the No. 9 mine on this creek the set-up is very similar to that on Dan Creek, but the piping starts at the lower end of the pit and advances upstream (see fig. 45). By alternating from one side of the sluices to the other the material is piped along a face which is at about right angles to the sluices or

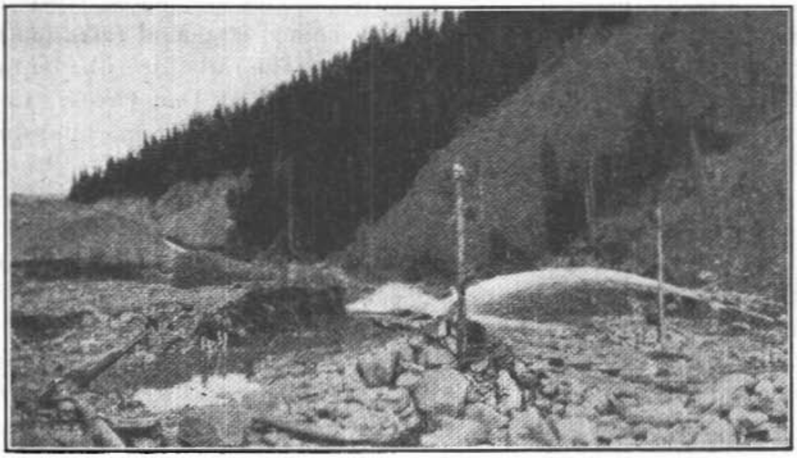


FIGURE 44.—Piping over the side on Chititu Creek

points slightly upstream. A shoulder next to the sluice is often left to the last as a protection to men clearing bowlders on the

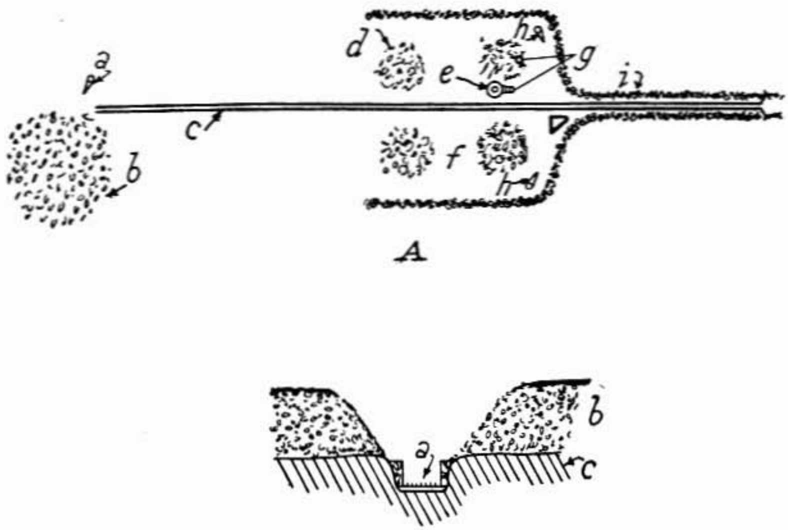


FIGURE 45.—Method of piping over the side, advancing upstream. *A*, Plan: *a*, Stacker giant; *b*, tailing pile; *c*, sluice boxes; *d*, bowlder piles; *e*, donkey hoist; *f*, pit; *g*, unworked ground; *h*, giant; *i*, bedrock cut. *B*, Section across bedrock cut, showing position of sluice boxes in relation to bedrock: *a*, Sluice box; *b*, gravel; *c*, bedrock

opposite side. In other respects the methods used at No. 1 and No. 9 Chititu mines are very much the same. The bowlders are loaded onto a steel stone boat operated by a donkey hoist and are piled on cleaned bedrock. The tailings are stacked by giant.

A special type of sluice box is used. Ties are placed crosswise in the bedrock sluice and to these are spiked 20-pound rails, placed lengthwise and spaced at 4-inch centers. The rails form the bottom of the sluice, the sides being boarded up as at Dan Creek. Caps are, however, used to keep the tops of the boxes from collapsing. The grade of the sluices at No. 1 mine is 5½ inches; at No. 9 mine it is 6 inches. The boxes are 3 feet in cross section, and those below the pit are constructed with the regular bottoms. The clean-up is conducted in much the same manner as at Dan Creek, but more easily, as the bedrock is generally softer and permits the cutting of a smoother sluice.

Operations in 1923.—In 1923 the No. 1 mine started a pit 900 feet long and averaging 150 feet in width, but about 150 feet at the lower end remained unfinished at the close of the season. The average depth of the deposit was 10 feet. There were 39,326 cubic yards hydraulicked in sixty-four 20-hour days. The cost of labor and board only for making the set-up, hydraulicking, and cleaning up is reported as 22 cents per cubic yard. At the No. 9 operation a pit 460 feet long, averaging 140 feet in width and 11 feet in depth, was hydraulicked in forty-four 20-hour days, the total yardage handled being 23,323 cubic yards. The cost of labor and board was 21 cents per cubic yard. In 1924 the two operations mined 99,180 cubic yards, the average depth being 9 feet, at a total operating cost of 51 cents per cubic yard. Thirty-five men were employed.

DISCUSSION OF METHOD

The method of piping over the side with the sluice boxes all set below bedrock as described is particularly adapted to the mining of creek placers that are comparatively wide and not too shallow, that contain unusually coarse wash and have low stream gradients. An ample, steady supply of water under high pressure for the giants and a large quantity of ground-sluice water are required. To insure a good recovery, the gold should be coarse and heavy. The placer deposit should be at least 10 feet deep, providing a large enough volume of gravel to justify making the extensive and costly set-up. The bedrock should be fairly regular and not too hard. With this method, the set-up for an entire working season can be made at one time; furthermore, virtually continuous use of the water is possible. No backstops are required, as the gravel faces serve for this purpose. The dip, strike, and contour of the bedrock largely determine the relative advantages of working up or down stream. Working downstream from the head of the pit permits taking advantage of the grade, the material moves in the general direction of the flow in the sluices, and hence on reaching them can be more readily transported than when the work is upstream. In the latter method the gravel is piped straight across or at an angle upstream, and on encountering the sluice flow may come practically to a dead stop and must again be put in motion. This has a tendency to block the sluices. However, where much fine material is present, the boxes can be easily overloaded by either system. The downstream system permits at any time a clean-up of the sluices as far as work has advanced, which is a valuable safeguard against theft and floods. However, with this system, when a pit is not completed by the end of the season the following season's work is handicapped, whereas with the system of working upstream it is a simple matter to extend the pit from where work was left off the season before.

PIPING OVER SIDE WITH LOWER SLUICE BOXES SET IN OR ON BEDROCK AND UPPER ONES ON OR ABOVE BEDROCK SURFACE

The chief benefit of raising the boxes is to obtain a steeper grade than the natural conditions afford. In order to pass through enough boxes to insure good gold recovery, the material from the lower part of the pit must be piped upstream to a certain point before it is piped over the side of the boxes. The tops of the boxes are usually above bedrock at and beyond this point, hence most of the material must be piped up the low incline of gravel alongside the boxes. Some of the pressure water does not reach the boxes, so more ground-sluice water must be turned in at the head.

The height to which the boxes are raised above bedrock is governed chiefly by the size of the gravel and the hydraulic pressure. When the heads of the boxes must be raised 8 to 10 feet above bedrock to obtain enough slope, it is generally better practice to drive the material from the upper part of the pit along to a point where it can be more easily washed over the side of the boxes. The pressure water should be under high head, so that most of the material can be readily piped up over the side and the pit made large enough to justify the set-up. The gravel should not be too coarse, otherwise unusual quantities of the larger stones may have to be handled and piled out of the way.

The method is used principally in the Fortymile, Circle, and Seventymile districts (fig. 1, *37*, *39*, and *41*), and to a small extent in some of the other interior districts where the creek placers are 8 to 12 feet deep after stripping.

PLACER ON EAGLE CREEK

On Eagle Creek, in the Circle district (fig. 1, *37*), a frozen creek deposit that averages 18 feet in depth and 150 feet in width is being hydraulicked; the central 60 feet have been mined by drift workings. In order to aid thawing and help sluicing, 6 to 8 feet of sandy overburden are stripped with the giants, usually a season in advance of actual hydraulicking. About 6 feet of medium-size pay gravel, 4 feet of sandy clay which pinches out at the edges of the channel, and 1 foot of schist bedrock are piped to the boxes. The gold is coarse. Most of the bowlders encountered are the remains of old rock piles

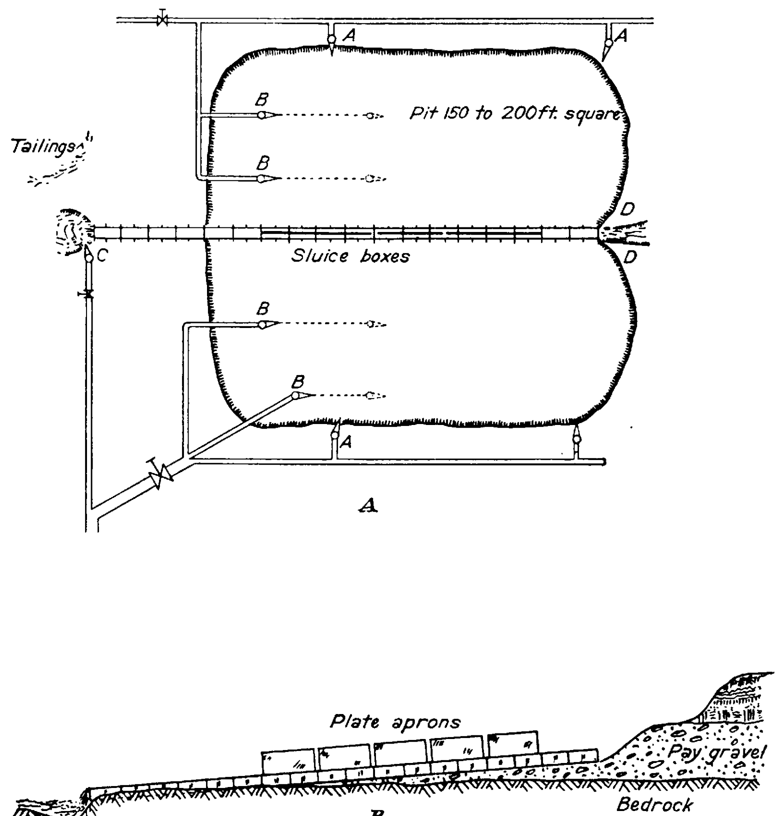


FIGURE 46.—Method of piping over the side as used on Eagle Creek, Circle district. *A*, Plan: *A*, *B*, and *C*, Giants; *D*, Unworked ground. *B*, Longitudinal section

from former drift mining. Many old drift timbers are also present. The average grade of the creek is 125 feet to the mile.

Equipment.—The general pit arrangement and sluice-box set-up are shown in Figure 46. A trench is first piped into bedrock and into the bank ahead, and three or four boxes are set on a 9-inch grade and light wings erected at the head. A head giant then pipes out to grade a cut down the center of the proposed pit connecting with these boxes. Ten or twelve more boxes are then installed on a 7-inch grade. Steel standards, fastened to each side of the boxes and meeting 4 feet above over the center of the boxes, support steel plates $\frac{1}{4}$ inch thick, 5 feet high, and 8 feet long, which hang from a $\frac{3}{4}$-inch pipe running from one standard to the other. Although it is the aim to pipe the gravel so it will just roll over the top of the boxes and into them, these plates are necessary to stop flying material and water from going beyond. During piping, the bottoms of these plates are fastened to the opposite side of the boxes, as the piping is generally done from only one side at a time.

The boxes are 36 inches wide (excluding the $1\frac{1}{2}$-inch liners) and are 24 inches deep. The bottom and sides are made of $1\frac{1}{4}$-inch material. A heavy timber with a quarter section cut out so as to fit over the top and upper outer side of the boxes is nailed along each edge as a protection from the piping.

The upper 10 boxes or those on 7-inch grade are paved with high-carbon steel plates $\frac{1}{2}$ inch thick and cut square so they can be turned as they become worn. These plates are laid on 2 by 4's running crosswise of the boxes, with a special spacing block placed to leave a 2-inch space, which acts as a riffle, between plates. These plates are used to save grade. The lower boxes are paved with 12-pound rail riffles set lengthwise, spaced at $2\frac{3}{4}$-inch centers with cast-iron spacers, and bolted together in sets 4 feet long.

Depending on conditions, the lower end of the boxes may be resting on bedrock, or a foot or so below, while the head of the boxes may be 6 to 10 feet above bedrock, so that the tops at this point are generally but a few feet below the surface of the gravel. Small wings are erected at the head to guide the ground-sluice water.

The average pit mined from a set-up is about 150 feet square. Eight field giants, four on each side of the boxes, are placed about as shown in Figure 46. These are equipped with $3\frac{1}{4}$-inch nozzles and use water under a 120-foot head. The stacker has a $3\frac{1}{2}$-inch nozzle operating under a 135-foot head. Normal water conditions permit the use of only one field giant and the stacker at a time, so the field giants not in use are "plugged." During low-water periods water is impounded in a ditch reservoir, necessitating intermittent operation or splashing for periods of about one hour; 8 to 10 of these splashes are necessary per 24 hours.

Explanation of diagram.—Giants *B*, which are first set on bedrock below the pit, pipe the material upstream into the field of giants *A* and also drive some of it over the sides. The giants *A* do most of the piping over the side. The upper giant *A* drives the material over the side at a point usually below the first or second upper boxes and also drives it into the field of the others. Giants *B* are, however, used mainly for taking up the lower gravel, clay, and bedrock and for final cleaning, and are advanced upstream in stages.

Giant *C* does the stacking, and along with the inner giant *B* drives the material lying alongside the boxes to points upstream for piping over. The boxes are last cleaned up and removed, then giants *B* and *C* drive ahead the remaining material which was left alongside and under the boxes and at points *D* onto unworked ground, to be recovered in the next pit. Giant *B* finally pipes the short trench for the lower three or four boxes to start the next pit.

Operating data.—The average crew consists of six men, and two 12-hour shifts are worked when water is available. A complete set-up for a pit, exclusive of moving the pipe lines, can be made in 24 hours. One set-up of the main pipe lines serves for two pits. During an average season two or three pits are mined. In 1921, 20,740 cubic yards were handled at an operating cost of 36.1 cents per cubic yard and in 1922, 49,860 cubic yards at a cost of 19.96 cents per cubic yard. During exceptionally dry periods only stripping ahead can be done, as the water supply is then too low to permit the regular hydraulicking. About $50,000 is invested in equipment and the 3 miles of ditch lines.

PLACER ON CROOKED CREEK

On Crooked Creek, in the Seventymile district (fig. 1, *39*), the creek deposit mined is 6 to 12 feet in depth, and the gravel is of medium size, with but few bowlders. Bedrock formation is composed of alternating beds of sandstone, shale, and conglomerate, some beds being harder and more resistant and forming occasional high ribs or reefs. A sticky clay sediment overlies all but the conglomerate formation. The average grade of the stream is 100 feet to the mile.

The deposit is stripped with giants well ahead of mining, leaving 5 to 6 feet of gravel and 1 to 2 feet of bedrock to be mined. The average pit mined is generally 125 feet long and 80 to 150 feet wide, depending on water pressure and the width of the pay. The trench is piped out and the sluice boxes are placed in much the same manner as at Eagle Creek.

Sluice boxes.—Ten to fourteen boxes are generally set on a grade of 8 inches to 12 feet. The lower end of the boxes is usually set just below bedrock, while the head is 1 to 3 feet above bedrock; in one set-up the head was 12 feet above, which was found to be much too high for good work. The boxes are 30 inches wide and 24 inches high, constructed according to a regular design of 1-inch sides and bottom, and paved with block riffles made up in sets and held in place by special lining boards bolted to the sides of the boxes. These liners are made up in sets 12 feet long, 2-inch boards being bolted together, making them high enough to come flush with the tops of the boxes.

Old boards or slabs are nailed lengthwise to the side braces of the boxes, and a 1½-inch board strip is nailed lengthwise along the top edge, so that the boxes are fully protected from the force of the piping. Board aprons or backstops are hung centrally along the boxes from standards of 2-inch pipe and are similar in principle and purpose to those used at Eagle Creek (see fig. 24). At some other operations board backstops are erected along one side of the boxes opposite to the piping instead of being hung from standards.

Operation of giants.—Four field giants are set—two on the bank near each upper corner of the pit (*a*) and two at the lower edge of the pit on bedrock (*b*). The field giants use 2½ or 3 inch nozzles, depending on the water supply. These now operate under only a 60-foot head, although 150 feet was available at earlier work farther down the creek. This low head is handicapping the operation and a higher ditch is being constructed. The stacker giant *c* with 3-inch nozzle operates under a 70-foot head. The set-up is very similar to that at Eagle Creek, and the piping is done in much the same way.

During low times of water the water is stored in the ditch reservoir and used intermittently for short periods. The average water supply permits the use of but one field giant and the stacker giant at a time; then the practice is to complete one side of the pit before the other side is piped. When a full head of water is available, piping is sometimes done from both sides at once. The lower giant *b* pipes the material diagonally upstream and as far to the head of the boxes as practical before it is put over the side by this giant and giant *a*, and the pit is piped well into bedrock. The material alongside the boxes at the lower end is then piped to the upper end by giant *b* and the stacker giant *c* and piped over the side. Bedrock is then given final cleaning with a hose and nozzle outfit. From 6 inches to 3 or 4 feet of bedrock are piped up. Boxes are then cleaned and removed and material remaining alongside and underneath is piped ahead on virgin ground for the next pit. Under normal operation the flow of material through the sluice boxes is about 6 inches deep. The bowlders are removed and piled by hand on cleaned bedrock, the larger ones being broken with a sledge. Six men are employed, and shifts of 12 hours are worked.

Operating data.—One pit of 18,750 square feet (about 4,170 cubic yards) was piped over the side in eight days with a full head of water available. About 220 inches of ground-sluice water were used, or about twice as much as the one field giant with 3-inch nozzle used under a 60-foot head. The total water used, including that for the stacker giant, was 455 miner's inches, giving an approximate water duty of 1.2 cubic yards. Twelve boxes can be installed, the giants set, the bedrock drain prepared, and everything made ready for a new pit 125 feet long by three men in eight shifts. Four men usually clean up the boxes in one shift. In 1922, with a steady water supply under a head of 120 feet, 34,000 square feet of ground 6 feet deep (7,555 cubic yards) were piped over the side in 10½ days of steady piping. Including the set-up and clean-up, 15 days were required. This record is the best that has been made here. Where the water is used intermittently, it generally requires 25 to 27 days to pipe over a pit 125 by 150 feet and 6 feet deep (4,180 cubic yards). During an average season, May 10 to September 15, about five pits, or 75,000 to 80,000 square feet, are completed, and the operating cost ranges from 5 to 7 cents per square foot, or 23 to 32 cents per cubic yard. About $5,000 is invested in the equipment and $5,000 in the ditch line.

PIPING OVER SIDE WHEN BOXES ARE ON OR ABOVE BEDROCK

A method of piping over only one side of the boxes, which were all elevated above bedrock and ran across or at angles with the channel, was used for a time on Moose Creek in the Kantishna district (fig. 1, 27). The creek deposit averages 10 feet in depth and contains unfrozen medium-size round gravel. The bedrock is a tough clay. A trench is first piped to grade in the gravel, crosswise or at an angle with the channel. Nine or ten lengths of sluice boxes 40 inches wide are then installed in this cut on a grade of 9 inches, which usually brings the top of the head box about 2 feet below the surface of the ground and the bottom of the last box a foot or so above bedrock. These boxes are heavily constructed and have timber guards on the lower side as a protection from the battering of the gravel. A heavy board apron or side about 8 feet high is erected along the upper side of the boxes.

Two giants with 3½-inch nozzles, under a 250-foot head, are set up about 200 feet or so downstream from the sluices, so that each can cover its field to the best advantage, and a third giant is placed so that it can pipe the material into the field of the central giant and also stack the tailing. A large quantity of water is turned into the head of the boxes, as much of the giant water does not enter them. The material is then piped upstream against the slight grade and toward the upper half of the sluice, then up the incline of gravel lying alongside the boxes and over their side, striking the apron and falling into them. As piping advances upstream bowlders are piled behind or at one side on cleaned bedrock. When all the material has been put through the boxes, except that directly alongside and under them, which is later driven on to the next set-up, the boxes are cleaned up and removed. While this hydraulicking has been under way another line of boxes has been installed about 200 feet farther upstream. Giants are then reset and the next pit mined. Very little time is lost between pits.

At a mine in the Yentna district (fig. 1, *26*) the boxes were elevated above the ground but placed lengthwise with the channel and the material was piped over the side, alternating from one side to the other. No hanging plates or backstops were used. The method as applied there did not prove advantageous.

COMBINATION OF PIPING OVER SIDE AND INTO HEAD OF BOXES

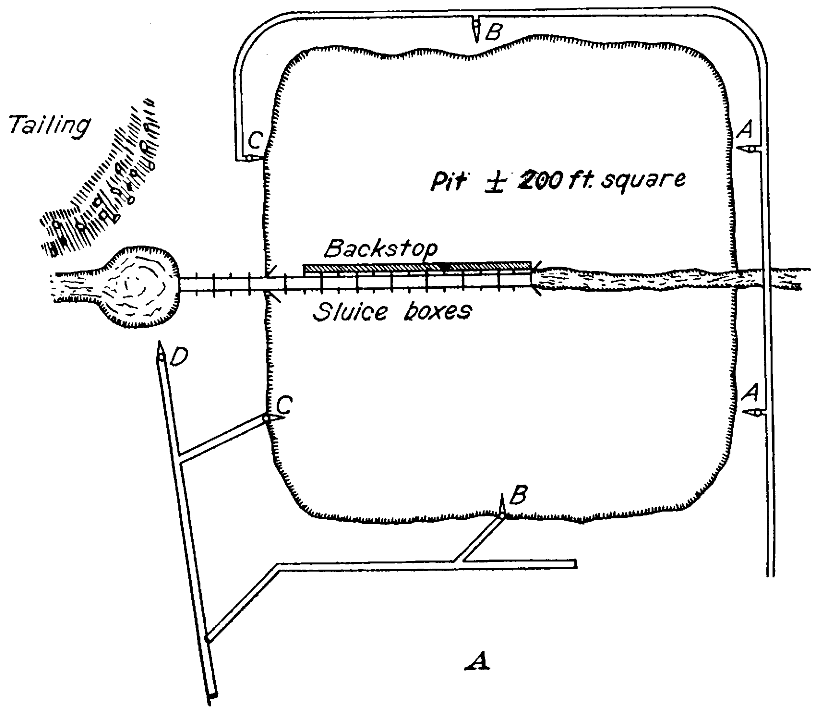
A combination of piping over the side and into the head of the boxes, often termed the "circle" system of hydraulic mining, affords some of the advantages of both methods. The combination method is particularly applicable to hydraulicking gravel of average size and medium depth where the grade is too flat for piping into the head, or where the bedrock and other conditions are unfavorable for piping over the side a pit of practical size. A longer pit can generally be mined than would be practical by some of the other hydraulic methods.

PLACER ON MASTODON CREEK

On Mastodon Creek in the Circle district (fig. 1, *37*) a frozen creek deposit which ranges from 15 to 20 feet in depth is being hydraulicked after being partly drift mined. The overburden is stripped with the giants well ahead of actual mining to aid thawing and reduce the depth to about 10 or 12 feet of gravel. The gravel is mostly of medium size and contains an average number of medium-size bowlders. Much of the schist bedrock is slabby, but most of it can be cleaned with a giant, although the crevices require hand cleaning. The average stream grade at the lower ground is 5 inches to 12 feet, increasing to 6 inches at the present workings farther up the creek.

Water supply.—The water supply is erratic, but under full head will supply one field giant and the stacker. During periods of low water about eight to twelve 10-minute periods, called "splashes," are used in 12 hours, the field giant alternating with the stacker giant. The pressure water is obtained from two ditch lines at different elevations, the average head being about 100 feet. The size of the crew varies according to the volume of water available. In a favorable season 10 to 12 men, working two 12-hour shifts, may be employed, whereas in an unfavorable season only one shift may be worked with two to four men.

Pits and sluice boxes.—Figure 47 shows the general set-up. At the lower workings the pits are usually about 200 feet long and 150 to 200 feet wide, but on the upper ground the pits are only 80 to 100 feet wide, mainly because of the narrower channel. When a pit is opened, three or four boxes are first installed on grade below the proposed pit, as deep in bedrock as conditions will permit, and small wings are erected at the head. The trench down the center is then piped out, the material going through these boxes. Then more boxes, usually 8 to 10, are placed in this trench, and heavier wings



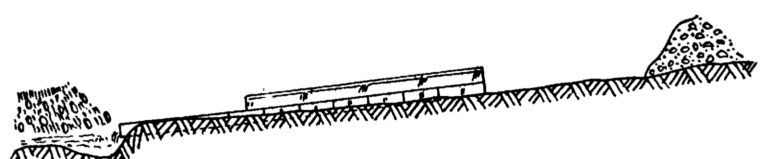


FIGURE 47.—Combination method of hydraulic mining (circle system) as used on Mastodon Creek. *A*, Plan: *A*, *B*, *C*, and *D*, Giants. *B*, Longitudinal section

erected at the head. These boxes are 32 inches wide and 24 inches deep, set on a grade of 7 to 8 inches. Block riffles (see fig. 24) are used. The head box is usually placed about the center of the pit and rests on bedrock; sometimes it is a foot or more above bedrock, but this should be avoided, for reasons stated under "Piping into the head." After the bank has been piped down level with the tops of the boxes a board backstop about 6 feet high is built along the side of the boxes, opposite the side being piped.

Giants.—The field giants are first placed on top of the bank as shown. In shorter pits the giants *B* may be omitted. When the water supply permits, $3\frac{1}{4}$-inch nozzles are used on all of the giants, and the amount from the ground sluices is about twice that provided by one field giant. The giants *C* pipe the material upstream, and with the aid of giants *B* drive it over the side of the boxes. The giants *A* drive some material into the field of *B* and also drive a little over the side, but they are used mainly for piping the material within their field into the head of the boxes. Giants *A* and *B* may later be moved down into the pit, especially if the bank is too high for efficient hydraulicking. In finishing the cut the material alongside the boxes is driven by *C* and *D* over the side or into the field of *A* and through the head box. The upper boxes are removed, and any remaining material is piped ahead to the next cut.

Operating data.—When this method is used on some creeks where grades are lower, and especially during a period of low water supply, the greater part of the pit is piped into the head of the boxes. With a full head of water supplying one field giant and the stacker steadily, one pit on the upper ground—100 feet wide, 200 feet long, and averaging 10 feet deep—was piped to the boxes in 21 days, four men working per 12-hour shift, at a cost of 10 cents per square foot, or about 27 cents per cubic yard. This area was stripped of 6 to 8 feet of overburden for 5 cents per square foot. With average "splash-water" conditions, it would have required about 50 days to pipe in the 10 feet of gravel and bedrock this pit contained. The average time required for installing 12 to 14 boxes, setting up the giants, and other preparatory work is three 8-man shifts. The average clean-up takes one shift. With an exceptionally good water supply, the operating cost for hydraulicking some pits by this method, exclusive of stripping, has been as low as 15 cents per cubic yard, but usually ranges from 25 to 50 cents per cubic yard.

DISPOSAL OF BOWLDERS

The generally low gradients and meager water supplies at most hydraulicking operations materially increase the amount of heavy material which can not be passed through the sluices, and its disposal decidedly increases the cost of mining. All of the material can rarely be passed through the sluice boxes, even after the larger bowlders have been broken. All rocks too heavy for sluicing are therefore piled to one side on cleaned bedrock or entirely removed from the pit. At small mines this is generally done by manual labor. Stiff-leg derricks, usually operated by hand, have proved very useful where there are many large bowlders and the pit is small (fig.

48). The bowlders may be loaded on a stone boat drawn by horse or mechanical power. The use of a steel stone boat operated by cables from a donkey hoist, as practiced on Chititu Creek, is shown in Figure 49.

FIGURE 48.—Difficult hydraulic mining in Iditarod district. Derrick for handling bowlders

Some mines are equipped with overhead cables stretched across the pit, along which traveling carriers are pulled by steam or water power. Wire nets or stone boats are loaded with bowlders, the trac-

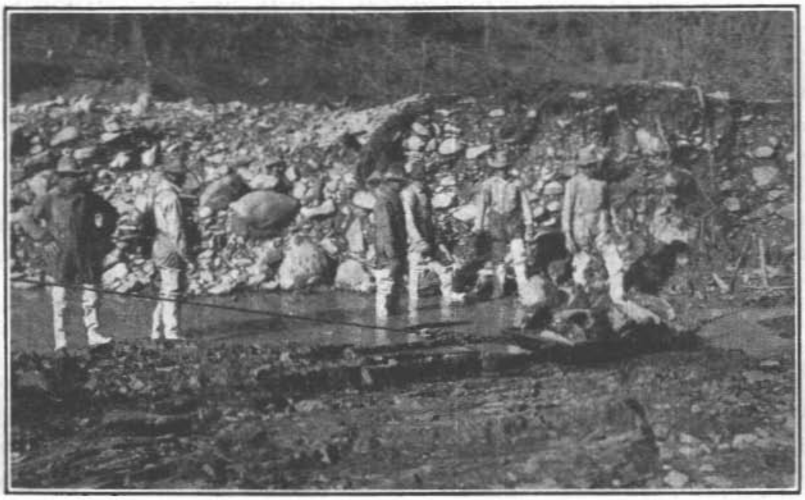


FIGURE 49.—Bowlder disposal. Loading the steel stone boat

tion cable is tightened, and the load of bowlders is hoisted to the carrier, hauled over the traction cable, and automatically dumped at the desired place. Large derrick-and-cable outfits, especially when operated by steam, have a very restricted field in Alaska.

The larger bowlders are generally broken to facilitate handling. The flat, soft, or friable ones can be readily broken by sledging. The more rounded, hard, tough bowlders are blasted, generally by "bulldozing" or "mud capping." However, at several of the larger hydraulic mines, such bowlders are drilled before being blasted (fig. 50), which makes a great saving in the amount of explosive required.

A deposit is being mined (fig. 1, *47*) on Dan Creek in the Nizina district, where an unusually large number of rounded bowlders, chiefly of greenstone, limestone, and slate, are encountered. All bowlders over 15 inches are broken by sledging and bulldozing and put through the sluice, except those 6 to 10 feet in size, which are undercut with the giants, rolled over, and left.

FIGURE 50.—Drilling a bowlder before blasting it, Crow Creek

At this property a total of 27,415 shots was fired during the season of 1922, or 357 per day. There were 14,075 pounds of 60 per cent straight dynamite used, costing 20.3 cents per pound. Including No. 8 detonators at $1.88 per box and triple-taped waterproof fuse at 92 cents per 100 feet, the total cost for explosives was $4,812, or 4.6 cents per cubic yard of ground mined. There was 0.59 pound of dynamite used per shot, or 0.13 pound per cubic yard mined; 0.26 shot was fired per cubic yard mined, or 3.8 cubic yards of ground mined per shot fired. Two men per shift are employed for this work.

On Crow Creek in the Girdwood district (fig. 1, *49*) about one-fifth of the material mined is hard, round bowlders of granite and graywacke. Some are sledged or "bulldozed" but most of them are drilled before blasting (fig. 50). All the material is put through the sluices. The usual bowlder crew consists of four men working one shift. Three air drills equipped with ⅞-inch hexagon steel are used for drilling. The depth of the holes is 5 to 30 inches, and 40 to 50 steels are used per shift. About 300 shots are averaged per day. In 1923, 1½ tons of 60 per cent dynamite costing $11 per box, 25,000 detonators, and 72,000 feet of fuse were used. The compressed air for the drills is produced by a 12 by 10 single-stage compressor, belt-driven by a 20-inch Pelton water wheel operating under a 150-foot head.

DISPOSAL OF TAILING

Tailing from hydraulic mines in the higher bench deposits can usually be dumped over the bank into the stream below. With grades generally not less than 12 inches in 12 feet, the tail boxes can be extended from time to time and the tailing spread over worked-out or barren ground. The grade of the surface must be much steeper than that of the sluice to provide ample room for the tailing below the end of the lowest box.

Creek deposits and benches only slightly elevated above the stream bed seldom afford these required conditions, and the tailing must be stacked. This stacking is usually done with a giant or, where water is scarce, by scrapers of the Bagley or slip-tooth type or by cableway excavator, operated by steam. It may be practical to use part of the water that would be required by the giant stacker to provide water power for a scraper. Horse-drawn scrapers were at one time used, but they have been replaced by the cheaper mechanical methods.

In stacking tailing with water under pressure the stacker giant is set beside the end of the sluice and the heavier tailing material is piped into a pile, the lighter tailing being carried down the bedrock sluice to the creek. On very low grades another giant is often set farther downstream to boost along this lighter material and keep the channel open (see fig. 51). Where there is much sand or fine material in the tailing to be stacked, the efficiency is lowered, as the fine material tends to run back into the sump. At some properties the stacking may have to be continuous, and at others an hour or two each shift may suffice; therefore the quantity of water required by a stacker giant varies widely and may range from one-fifth to the total amount required by a field giant. Where there is much heavy material or tailing room is limited, the stacker giant may require even more water than a field giant.

On Dan Creek tailing that holds many bowlders, some 15 inches in size, has been stacked to a height of 52 feet by a giant with 4-inch nozzle under 310-foot head.

At one mine on Mastodon Creek in the Circle district (fig. 1, *37*) tailing was stacked to a height of 35 feet without difficulty by a 3-inch nozzle under 100-foot head, the biggest stones being about 12 inches in largest dimension. The tailing was at one time piped up an inclined chute 4 feet wide and 3 feet deep, the bottom of which was fitted with beveled steel-shod riffles set at an angle to keep the sand and fine material from running back into the sump. In general, the tailing can be stacked to a height of one-third the head on the giant in feet and at a distance from the giant of one-half the head. The height and length of the tailing pile are, however, also governed by the character of the material; so for efficient giant stacking under average conditions the face of the pile should be kept as long as practical and at an angle of slope not exceeding 25°.

Former practice in tailing disposal at Crow Creek was to extend the sluices as the tailing accumulated. This required the addition

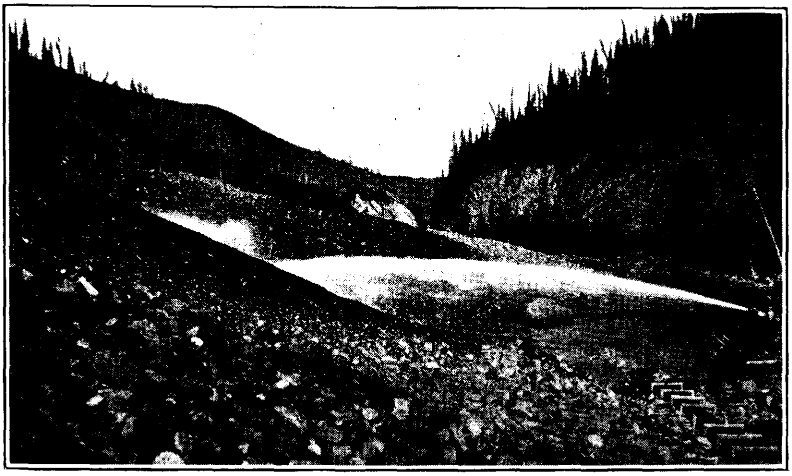


FIGURE 51.—Stacking tailing with the giant

of one or two boxes a day, so that the sluice eventually contained 60 to 90 boxes. As enough water under pressure is available, 8 to 10 boxes set on 6-inch grade are now used and the tailing is stacked with a giant. This method has been found to be more practicable and cheaper than the old method.

Although there are no débris laws in Alaska, tailing should not be dumped indiscriminately into the stream beds, but preventive measures should be taken to impound it, so it will not be eventually deposited over workable ground, the property of another, or pollute his water supply. Fortunately there are now few instances where this involves a serious problem or expense. Proper stacking partly overcomes this, although in narrow valleys subject to high floods exceptionally strong dams may be required.

HYDRAULIC MINING COSTS

Hydraulic mining in Alaska normally costs 25 to 50 cents per cubic yard, including seasonal preparatory work, labor and board, maintenance of ditching, general supplies, and other operating expenses, but excluding overhead or capital charges. Wages, with board and lodging, generally constitute 85 to 95 per cent of the operating cost.

If an ample water supply is available and other conditions are generally favorable, it is possible to mine for less than 25 cents, while under adverse conditions the cost may reach 75 cents to $1 per cubic yard. There are several instances known where hydraulicking has cost over $1 during an adverse season.

Some hydraulicking has been done, particularly on the deep benches, for about 10 cents per cubic yard, but conditions were exceptional. Years ago the deep lake-bed deposit near Juneau was hydraulicked for around 6 cents per cubic yard under very favorable operating conditions. In general, it can be stated that the operating cost over a period of years will rarely average less than 20 cents per cubic yard for the hydraulicking of bench deposits and 25 to 30 cents per cubic yard at the creek operations, and only then when conditions are more favorable than usual. The cost of hydraulic mining at any particular operation is largely determined by the water supply, therefore a comparatively low cost may be realized during a favorable season, while during a dry one the cost may be two or three times higher.

COSTS OF TYPICAL MINING PROJECTS

Some typical mining costs have already been given; others are given below. Near Nome one placer in creek gravel 16 feet deep cost 30 cents per cubic yard, another in 6-foot ground, 26 cents. Both stacked the tailings with a giant. In the Iditarod district, on the Upgrade Association property, almost unlimited grade is available, but other conditions are adverse for hydraulicking (fig. 48). The cost there ranges from 50 cents to $1 per cubic yard, and in some of the creeks near by, 35 to 50 cents. In the Yentna district, where the water supply is fairly reliable, unfrozen medium-size creek gravels 5 to 9 feet deep are mined for 5 to 7½ cents per square foot, or 25 to 35 cents per cubic yard. During unusually dry seasons the cost may be 40 to 50 cents or more.

In the Hot Springs district four small placers on shallow high bench deposits, averaging 5 to 10 feet deep, were hydraulicked in 1922 with water under heads of 30 to 80 feet, mostly used in "splashes," at costs of 3½ to 7½ cents per square foot, or 19 to 27 cents per cubic yard. A total of about 200,000 square feet, or 45,000 cubic yards, was mined at these four workings during the season. No stacking of tailing was necessary. Another better-equipped plant near by under similar conditions mined 40,000 cubic yards averaging 7 feet in depth for 15 cents per cubic yard. During a previous year with steady water a somewhat larger area averaging 6 feet in depth was mined there at a cost stated to have been 12 cents per cubic yard.

In the Fairbanks district 15 feet of frozen creek ground were mined for 54 cents per cubic yard. Gravel was heavy, and the creviced blocky bedrock required hand cleaning. Tailing was stacked by giant. In the Rampart district a low-lying sloping bench 10 to 40 feet deep, composed of 8 to 10 feet of gravel overlain by muck, all frozen, cost 20 cents per cubic yard. All the material went through the boxes. The tailing was stacked. One mine on the Kenai Peninsula hydraulicked creek gravel 6 feet deep during one season, with a large water supply available under a 300-foot head for 20 cents a cubic yard.

HYDRAULIC ELEVATORS

Hydraulic elevators are inefficient machines but are adapted to mining placers where conditions do not favor ordinary hydraulicking or dredging, but where an abundance of cheap water under high pressure is available. They are chiefly used to provide satisfactory sluice gradients and dump room in mining flat-lying placers and those where bedrock lies below the drainage level, so that the workings can not be naturally drained.

The gravel should be comparatively small, otherwise it may be necessary to remove an excessive quantity of stones too large to enter the throat of the elevator. Elevator practice has special advantages in placers containing stiff, sticky clay, as the clay is further disintegrated and washed when it is sucked up the elevator, strikes the hood, and falls into the sluices.

Hydraulic elevators are used principally on the Seward Peninsula, where favorable water supplies are generally available. They are but little used in the interior districts, where some half dozen operations have small elevators with lifts of 6 to 15 feet. There are, however, some creek deposits being hydraulicked and the tailing stacked where the use of an elevator would be more practical, although in general the field of use for the elevator in Alaska is very limited.

PRINCIPLE OF OPERATION

The principle of the hydraulic elevator is similar to that of a steam injector, in that a jet of water under pressure causes suction which draws a stream of air, water, and gravel through the intake and forces it up an inclined pipe, discharging into the sluice. There are a number of well-known makes of hydraulic elevators that act on this principle but differ in details of construction. One make has an auxiliary inlet on each side of the main intake for use when the main intake chokes; by extending these inlets the low places in bedrock can be drained. Its general construction produces higher efficiency and tends to reduce the wear and tear on the machine.

Proper regulation of the amount of air admitted and correct adjustment of the dimensions of the elevator, more especially the nozzle, throat, and upraise pipe, are of main importance in elevator construction. Hydraulic elevators are made in various sizes, with throats 5 to 18 inches in diameter and upcast pipes 8 to 30 inches, and for use with nozzles 2 to 8 inches in diameter.

The importance of an abundant water supply under pressure is explained by the fact that one-half to two-thirds of the available pressure water (generally the higher amount) is required by the elevator, leaving only the smaller portion for breaking down and driving the material to the elevator. The capacity varies with the ratio of the pressure head to the height of lift, and the effective head and volume of the water, the regularity of the flow of water and material to the elevator, and the duty of the water from the giants. The latter is a principal factor in determining the size of an elevator. The weight of solid material that the elevator will lift under ordinary conditions is usually about 2 to 3 per cent, at the most 5 per cent, of the total weight lifted. Much seepage water reduces the capacity of the elevator and chokes it. A water lift, which is virtually a small elevator with a suction pipe instead of an open intake, must often be installed to handle this excess water.

The proper angle of inclination for the elevator pipe depends on the character of the ground and the friction of material in the pipe, and may vary from 42° to nearly vertical, but is generally 60° to 70°. The height to which the material can be elevated is ordinarily 10 to 20 per cent of the effective pressure on the elevator nozzle, although by the use of compound lifts the height of the lift may be nearly doubled. The depth of ground that can be mined depends on the pressure head available, the size of the material, the inclination of the upcast pipe, and the height above bedrock surface at which the sluices must be placed to obtain the necessary grade. The pit should be deep enough to permit mining a large area from one set-up of the elevator, but not so deep as to require excessive lifts. Depths of 18 to 25 feet are generally considered most favorable under average conditions.

ARRANGEMENT OF EQUIPMENT

Hydraulic elevator pits, as mined in Alaska, are generally about 1 to 5 acres in area. When an area is opened, a pit 10 to 15 feet square is sunk from the surface to 6 to 10 feet in bedrock. The elevator is installed in this pit, which should be located at the lowest point of bedrock to insure good drainage. In wet ground a water lift may be required in sinking the pit, and some timbering may be necessary. Some elevators are so constructed that they can be set up on the surface and will sink their way to bedrock. After elevating is under way and much seepage water must be handled another sump is dug several feet deeper in bedrock and a water lift is installed.

The part of the elevator exposed to battering by material from the giants is usually protected by a board covering. After the elevator has been installed and securely braced the sluice boxes are set (fig. 52). The upcast pipe enters at the bottom of the head box. This head box is inclosed at the back and top, and the latter is protected by a striking plate or a curved hood of heavy manganese steel. The head box has a grade of 4 to 5 inches; the grade of the other boxes increases 1 inch on 12 feet after every two or three boxes.

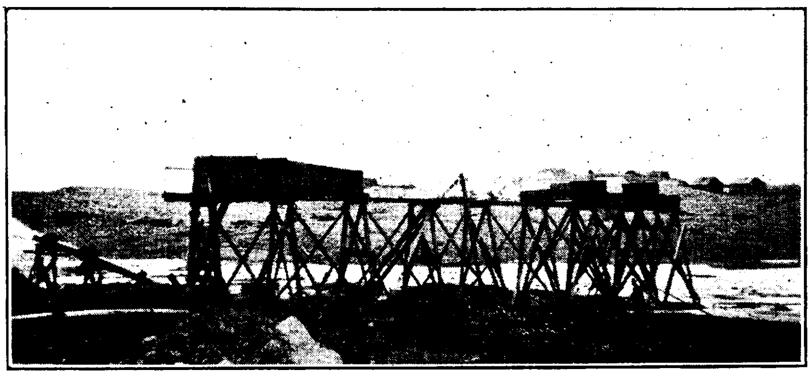


FIGURE 52.—Installing hydraulic elevator and sluice boxes near Nome

The tailing is generally dumped into a worked-out pit, but may have to be removed from the end of the sluice and stacked by a giant, as occasion demands. The field giants are first set on top of the bank, and as the pit widens are moved down into it (fig. 53). In large pits the material is piped along to the booster giants, which drive it to the elevator. The system of piping is similar to that for piping into the head. The material may be piped into bedrock sluices leading to the elevator, and often steel chutes are laid on bedrock to transport the material. The elevator will take bowlders about one-half inch smaller than the diameter of the throat. The oversize must be kept away, and at many plants a grizzly or grating to keep out oversize is placed ahead of the intake.

Where seepage water is troublesome, it may be necessary to leave a strip of ground between the pit and the creek channel, or between different pits. At one mine the elevator was installed with its back to a completed pit, and after the elevator was started a dam reinforced with brush was built, between the new and the old pits, with tailing from the sluices.

ELEVATOR MINING ON LITTLE CREEK, NEAR NOME

The largest elevator workings in Alaska are on and near Little Creek in the vicinity of Nome, but since the large dredges were started there mining with elevators has been greatly reduced in scale and will soon be discontinued. The deposits mined range from 15 to 40 feet in depth, and except for some small irregular areas are permanently frozen. The moss and 2 to 10 or more feet of muck and top gravel are first removed with giants, much of this material being elevated. The depth and character of the gravel vary but it is mostly of medium size with an average amount of bowlders.

FIGURE 53.—Opening elevator pit, driving to elevator

Clay is mixed with much of the gravel and overlies some of the bedrock. The bedrock is slate, schist, and limestone, the latter being very slabby, creviced, and irregular.

Up to 1923, during each annual working season elevator mining at Little Creek was usually conducted in four pits, each completed pit ranging from 3 to 5 acres in area. A total of 100 to 125 men was employed. The average operating season was from about June 10 to October 15. All of the pits could not be worked throughout the entire season, but 350,000 to 550,000 cubic yards, depending on the water supply, were mined each season, or 1,000 to 1,500 cubic yards a day per pit. Two 11-hour shifts were worked with 10 to 15 men and one or two teams of horses in each pit. The available head of the water delivered to the pits is 290 to 310 feet. Although six or more field giants were eventually set up in a pit, as a rule only two giants and the elevator were working at the same time.

EQUIPMENT

The field giants were usually equipped with 3-inch and $3\frac{1}{2}$-inch nozzles, but $2\frac{1}{2}$-inch sizes were used when the water was low. In each pit was an hydraulic elevator with 10-inch throat and 18-inch upcast pipe. As a rule, elevator nozzles $4\frac{1}{4}$ inches in diameter were used for lifts up to 40 feet and a larger size for higher lifts. The elevator was set on an angle of 62.5°, the lift ranging from 30 to 55 feet. Each elevator used 450 to 550 miner's inches of water, a total of 750 to 1,000 inches at each pit. The tailing was stacked at intervals by a giant with a 3-inch nozzle. Booster giants were used and, in rough bedrock, steel sluices. All oversize rocks were loaded onto stone boats and hauled by team to one side or out of the pit.

The hood or head box was 12 feet long, 4 feet wide, and 4 feet high, and paved with block riffles. The other boxes were of steel, 8 feet long, 4 feet wide, and 2 feet high. The head box was set on a grade of 5 inches on 12 feet; the upper four to six boxes had a 6-inch grade, and the rest a 7-inch. From 150 to 180 feet of these sluice boxes were set and equipped mostly with 16-pound rail riffles placed lengthwise and some angle-iron riffles placed crosswise. The rails were bolted together in sets, with $1\frac{1}{2}$-inch spaces. The corner of each set was fitted with a cast-iron block and the blocks joined; a square steel bar could be fitted into them and keyed under a steel shoulder running lengthwise along each side of the boxes to hold the riffles in place. There was much fine rusty gold that was difficult to save, so on some sluices the lower 24 feet were made 8 feet wide and given a little higher grade.

About three days were generally required for sinking a pit through the gravel and 8 or 10 feet into bedrock, and one day to install the elevator. The elevator throats were of manganese steel and replaceable. When lifting sand, gravel, and bedrock they lasted about three months or would handle about 100,000 cubic yards; in this time they had become enlarged to 13 or 14 inches. The gold was mostly heavy, and very little was recovered in the head box, most of it being caught in the next two or three boxes. Virtually no gold was recovered in the elevator sump. One season's clean-up recovered only 7 ounces from the sump. The crevices and potholes were cleaned by hand, 10 to 25 men doing this work, and the material was wheeled to the elevator or often shoveled into small sluice boxes set up for this purpose. Unless this material contained from $2\frac{1}{2}$ to 3 cents worth of gold to the pan, its recovery seldom paid.

COST AND PRODUCTION

In 1921, when four pits were being worked, 550,000 cubic yards were mined at an average operating cost of 35 cents per cubic yard, including about 3½ cents for maintaining ditches. The average annual operating cost has been 40 to 50 cents per cubic yard. The average duty per miner's inch of all the water used in frozen ground was 1 to 1¼ cubic yards, and in partly frozen ground, 1¼ to 1¾ cubic yards.

HYDRAULIC ELEVATOR MINING ON INMACHUCK RIVER

On the Inmachuck River a hydraulic elevator with a 9-inch throat, a 4-inch nozzle, and a lift of 37 feet and set on a 62° angle is used under a 350-foot head. Two or three giants and one stacker giant with 3-inch nozzles are used (see fig. 54). Two shifts of 10 hours each were worked—six men on the day shift and three at night—in the pit: six men were also employed on the ditch. The

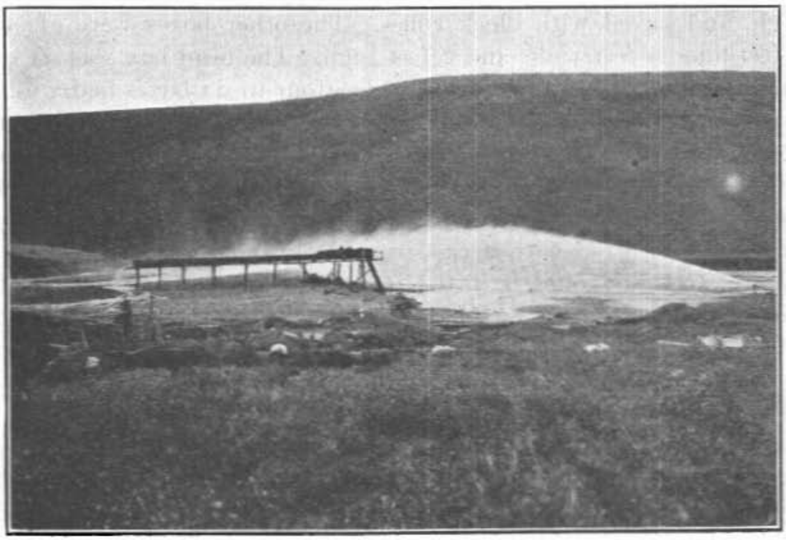


FIGURE 54.—Elevator and sluices

deposit is frozen and averages 20 to 25 feet in depth, about half being muck overburden which is first removed.

In 1924 a pit 315 by 460 feet was mined at a cost of 17.2 cents per square foot. About 53,000 cubic yards of gravel and bedrock were put through the elevator in 64 days at a cost of 47 cents per cubic yard. The cost in 1923 was about 35 cents per cubic yard. The average operating season is 85 to 90 days.

HYDRAULIC ELEVATOR MINING ON OSBORNE CREEK

On Osborne Creek a hydraulic elevator with a 10-inch throat and 4-inch nozzle, operating under a 170-foot head and on a 72° angle, lifts 15 feet. The deposit, which is partly frozen, averages 9 feet in depth and is coarse gravel; the bedrock is clay and is easily cleaned with the giants. Two giants with 3½-inch nozzles are used in the pit, and tailing is stacked at intervals with a 3-inch nozzle. From 65 to 72 feet of sluice boxes 3 feet wide, set on grades of 7 or 8 inches on 12 feet, are used in the set-up. The head boxes are paved with rail riffles, set both crosswise and lengthwise with the bottoms up. Block riffles are used in the other boxes. Usually about 2½ feet of sod and light overburden are stripped before the elevator is used. The pits are 200 to 250 feet wide by 175 to 200 feet long. With average water a pit is completed in three weeks. Ten men are employed. Except for the heavy wash, operating conditions are favorable. The operating cost is 20 to 35 cents per cubic yard.

HYDRAULIC ELEVATOR MINING ON OPHIR CREEK

The Wild Goose Mining & Trading Co. formerly conducted large elevator operations on Ophir Creek in the Council district (fig. 1, *4*) and from 1908 to 1910 handled 96,000 to more than 150,000 cubic yards annually of gravel averaging 8 to 11 feet in depth. The working costs, including all mining charges, depreciation on equipment, and charges for management, were 11.82 to 18.41 cents per square foot, or 39.6 to 46.2 cents per cubic yard.[43]

More recent elevator work at this property was in ground 4 to 10 feet deep where most of the bedrock was slabby limestone, very irregular and difficult to clean. Mining was conducted during only part of the working season, depending on the surplus water supply in the ditch and the length of time that could be spared from dredging by the hydraulic crew of five men. From 1918 to 1921, inclusive, a total of 96,885 cubic yards was elevated at an average operating cost of 31.27 cents per cubic yard, exclusive of depreciation and management, but including the proportional charge for ditch maintenance. It is customary at this operation to charge depreciation on equipment only at $1,000 per year, but this item is not included in the following table of operating cost.

Hydraulic elevator mining costs, Wild Goose Mining & Trading Co., Ophir Creek

	1918	1919	1920	1921
Labor	$3,648.50	$4,339.70	$5,281.10	
Board and lodging	1,351.60	1,545.46	1,744.80	
Supplies	89.55	10.25	71.25	
Freight and team	683.09	780.85	482.77	
Ditch maintenance	1,968.43	1,017.35	756.75	
Melting and transport	84.56	35.30	53.04	
General expense	450.61	337.98	233.80	
	8,276.34	8,066.89	8,623.51	$5,327.39
Area mined ... square feet			84,125	65,660
Average depth ... feet			9.34	7.7
Cubic yards mined	38,040	11,050	29,111	18,684
Cost per cubic yard ... cents	21.76	73.00	29.62	28.52

[43] Munroe, C. H., and Lanagan, W. H., Mining Engineers' Handbook. 1918, p. 792.

HYDRAULIC ELEVATOR MINING IN IDITAROD DISTRICT

Two small properties in the Iditarod district (fig. 1, *21*) are being mined by hydraulic elevator. The deposits, including top soil, are 12 to 16 feet deep and the overburden is first removed, leaving 4 to 6 feet of material to be elevated. An area of 20,000 to 35,000 square feet of bedrock is mined per season at each mine, by a crew of four to six men. The elevators are made of heavy pipe 8 inches inside diameter, with a 2½ or 3 inch nozzle fitted to the bottom. The material enters through an opening cut out of the side of the pipe. The elevators are set at angles of 78° and operate under 45 to 55 feet of head, with lifts of 6 to 8 feet. From 36 to 72 feet of 24-inch sluice boxes are used in the set-ups. One giant with a 1½ to 2½ inch nozzle pipes the material to the elevator. During the greater part of the working season water is only available for intermittent use. The tailing is periodically stacked with a Bagley scraper. The operating costs average 45 to 55 cents per cublic yard.

RUBBLE ELEVATORS

Rubble or grizzly elevators can be used under conditions similar to those required for hydraulic elevators, but the pit must have natural drainage. The advantages of the rubble are its comparatively low first cost (as it can be constructed at the property), ease of moving, and capacity for handling heavy bowlders. Haley [44] states that it was successfully used in California. The rubble has been used at a placer on the Kenai Peninsula and at several placers on Seward Peninsula. The only rubble elevator now being operated in Alaska is on Candle Creek (fig. 1, *6*), Seward Peninsula.

The elevator on Candle Creek is an inclined chute 8½ by 52 feet, with 10-foot sides at the lower end and 6 feet at the upper (fig. 55). It is set on a slope giving a 17-foot elevation at the top or discharge end. The lower 22 feet and the detachable apron have a solid bottom. The upper 30 feet has a bottom of steel-shod grizzly bars of 2½ by 5½ inch timbers set transversely and spaced 1¼ inches apart. Underneath the grizzly is a chute sloping down to the sluice boxes. All parts subjected to scouring are lined with $\frac{3}{16}$-inch steel. The sluice boxes, which are set at right angles to the elevator (fig. 55), have a total length of 36 feet, are 4 feet wide, slope 1 inch on 1 foot, and are paved with steel-shod Hungarian riffles. The framework rests on two heavy sills, mounted on rollers. Four men with a capstan and cable can move the elevator. It weighs about 15 tons and cost about $3,000.

The deposit mined is frozen and varies in depth, but the muck overburden averages about 30 feet and the gravel 7 feet. The gravel

[44] Haley, C. S., "Elevating 10-cent gravel at a profit; rubble elevator operation": Min. and Sci. Press, vol. 104, Apr. 13, 1912, p. 530.

is of medium size, with few bowlders over 1 foot thick. Most of the gold is coarse. The bedrock is schist and has a grade of 1.6 feet on 100 feet. The muck is first removed by hydraulicking to permit thawing, at a cost of about 5 cents per cubic yard. The average depth mined with the elevator is 9 feet, including 1 or 2 feet of bedrock.

The elevator is set at the lower end of the proposed cut, the lip of the apron being set 1 foot in bedrock. Two-inch board wings are erected on each side.

OPERATING DATA

The average pit mined with the elevator from one set-up is 75 to 100 feet wide and 300 feet long. A giant with a 4-inch nozzle is placed about 50 feet from the elevator, and two or more field giants

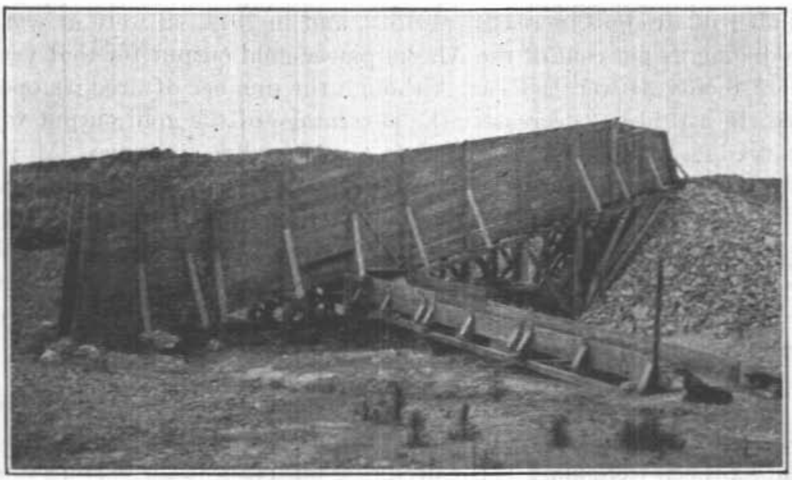


FIGURE 55.—Rubble elevator on Candle Creek, Fairhaven district

with 3 to 3½ inch nozzles drive the material to the elevator giant. This giant drives small quantities at a time up the elevator. The fine material containing the gold is washed from the heavy rocks, then washed through the grizzly. Unless this is carefully done much of the gold may be lost. A swinging gate or apron near the upper end of the grizzly aids in keeping any fine material from being driven over the top. The heavier rocks, when washed clean, are driven up and over the top of the grizzly. When the rock dump builds up, planks are laid thereon and the pile is extended, often higher than the elevator. When the height exceeds practical limits the pile is flattened with the stacker giant. The tailing from the sluice boxes is stacked as occasion demands. With 400 miner's inches of water under a 200-foot head, an average of 600 cubic yards can be mined in 24 hours; giving an average water duty of 1½ cubic yards. Three to four shifts are required for a new set-up. Three to four men are engaged in the elevator pit per shift. Usually enough water is available for mining about 50 days of each working season. From 20,000 to 40,000 cubic yards of gravel and bedrock are elevated during a season, and from 75,000 to 100,000 cubic yards of muck are stripped.

DREDGING

HISTORY OF DREDGING IN ALASKA

The first gold dredge in the Yukon was started on the Lewes River in 1899. During that same year a dredge was started on Snake River at Nome, although active dredging really began in 1903 with two small dredges on the Seward Peninsula. Gold dredging started in the Fortymile district (fig. 1, *41*) in 1907 and in the Iditarod, Circle, and Fairbanks districts (fig. 1, *21*, *37*, and *33*) in 1912. The number of dredges increased rapidly, and in 1914, 42 were at work, producing 22 per cent of the Alaska placer-gold output for that year. In 1916 only 34 were active. Although the number of dredges operated since 1914 has decreased, the percentage of the gold output won by dredges has increased. In 1923, 25 dredges produced 51 per cent of the annual placer-gold output. In 1924, 28 dredges operated; 18 of these were on the Seward Peninsula and 10 in the interior districts, although four of the Seward Peninsula dredges ran for only about one month. Annual statistics on the number of gold dredges operated, the production, and the average quantity of gold recovered are given under "Production."

FUTURE OF DREDGING

Although many dredges have been operated in Alaska and much gold has been won, most of the dredging has been conducted on a comparatively small scale, due mainly to operating conditions and the character and extent of the deposits. The more favorably situated, richer, shallower deposits were dredged first, and permanently frozen areas avoided as much as possible. Recent advances in cold-water thawing have been of the greatest importance to Alaska gold dredging by making possible the working of large areas of so-called low-grade ground formerly regarded as too lean or too deep to be successfully thawed. The development of the Diesel engine and other means of reducing power costs and improved transportation facilities to the interior districts served by the Alaska Railroad have also favored dredge operation and development. Conditions have become more satisfactory for acquiring the different small holdings necessary to make a dredging area. Two fields in Alaska have been made available for large-scale operations. The year 1923 witnessed the beginning of such operations at Nome, and all indications point to an extensive dredging program in the Fairbanks district.

Alaska gold dredging is entering a new era, with prospects for success, particularly in the Nome, Fairbanks, and Kuskokwim districts. Much encouraging prospecting has been done during the past few years, and the results indicate that six or eight new dredges will be started within the next two or three years. Some small dredges that have been idle will resume operations in the near future, although five or six of the present active dredges soon will have exhausted their ground.

FACTORS DETERMINING DREDGING

Dredging possibilities in Alaska lie mainly in deposits formerly mined by other methods, including creek placers, low benches, elevated beach lines, and gravel plains. In these known fields low-grade gravels and wet areas that could not be mined successfully have been left. In former mining gold was lost in the tailings, and much gold may have been left where creviced, slabby bedrock was encountered. In fact, it has become almost axiomatic among dredge operators on the Seward Peninsula that any ground can be dredged profitably which has been worked profitably by hand methods, even when it has been worked over several times. Although the fact that such ground has produced gold is indicative, it is risky to install a dredge without thorough prospecting. Numerous failures have resulted from such procedure; prospecting is especially necessary in ground that has been cut up by former mining. Known placers that have not been mined to some extent, except possibly thawed, water-soaked deposits or properties acquired by dredging interests soon after discovery, seldom contain enough gold for profitable dredging.

Experience and sound judgment are essential in determining the dredging possibilities of a deposit. All the physical and economic features affecting dredging must be determined before a dredge best suited to a particular deposit can be selected. A volume of gravel must be assured which will repay all invested capital and leave a net profit commensurate with the undertaking. The surface conditions, the depth and character of the overburden, the value, character, and distribution of the gold or other valuable content, the depth, character, and extent of the deposit, the presence and extent of frost, the character and contour of bedrock, and the underground water level should all be determined by prospecting. Accessibility, transportation facilities, climate, length of the operating season, water supply, cost of labor, supplies, fuel, or power, and the cost of the property or royalties, taxes, and titles must be investigated, as all of these features affect mining costs. Adverse factors that reduce the digging capacity of a dredge and may prevent profitable dredging include frozen ground and the presence of stiff or sticky clays, bowlders, slabby or hard bedrock, and high bedrock gradients.

DATA ON DREDGES

The following tables on Alaska gold dredges have been compiled from field data and from operators. Each season shows changes in the number of dredges operated, location, management, and mechanical detail. Eight or ten dredges that have been idle for a number of years and show no indication of future activity have been omitted. The tables are as complete as it is practical to make them. The daily yardage dug by the dredges fluctuates, but many of the figures given are averages derived from operating data. The amount of water used for sluicing can be stated only approximately. The table giving the physical condition of the placers dredged by the different dredges explains in a general way the application of the different sizes and types of dredges, daily yardage handled, and some of the difficulties that may be encountered.

TYPES OF DREDGES

The bucket dredge of the single-lift type is now the only kind in use. During the early days of dredging around Nome many so-called land dredges, often of freakish construction, were operated for short periods. Dipper and suction dredges were also tried, but none of these was a success. Moreover, many of the earlier bucket dredges failed.

Selection of the wrong type or size of dredge has often led to failure. Many dredges are too large for shallow deposits, necessitating the digging of much additional bedrock or the construction of dams to float them. In general, large dredges are unsuitable for Alaska, except in the more accessible districts (such as Nome and Fairbanks) where a large volume of gravel 20 or more feet deep is assured. The size is also governed by other operating conditions and the capital available. The most practical sizes for average Alaska conditions are the 2½ to 5 cubic foot bucket dredges.

As a dredge is usually far removed from the source of replacements, it should be strongly constructed to lessen possibility of a serious breakdown. The dredge is put in repair before starting and is expected to operate throughout the season. One serious breakdown may cause the loss of much time and money. A large stock of additional parts should be kept on hand, and in isolated districts a machine shop must be maintained. An oxyacetylene welding outfit is indispensable for repairing broken parts, building up tumbler plates, mending buckets, etc.

FLUME OR SINGLE-SLUICE DREDGE

The flume or single-sluice type of dredge has been developed for dredging relatively narrow, shallow, rich creek placers with coarse gold in easily washed material. Flume dredges are of light draft

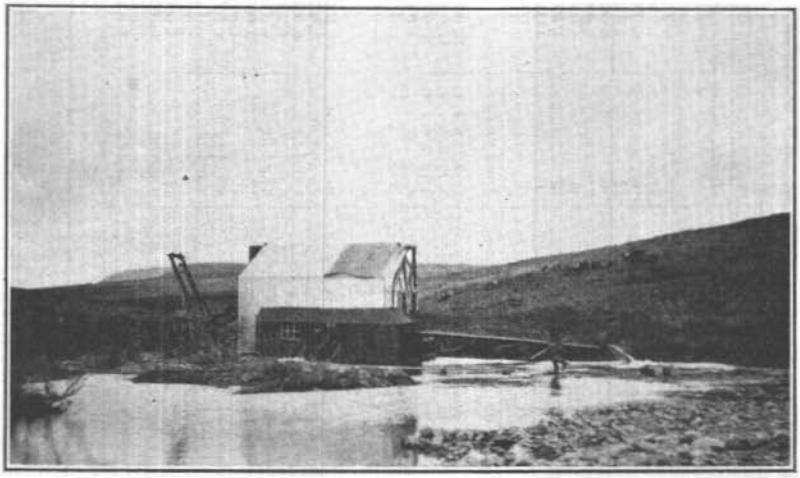


FIGURE 56.—A 1¼-cubic foot flume dredge, formerly on Warm Creek

and construction and are usually operated by distillate engines. The buckets discharge directly into the head of the flume, and the tailing is dumped astern. The depth of ground that can be dredged ranges

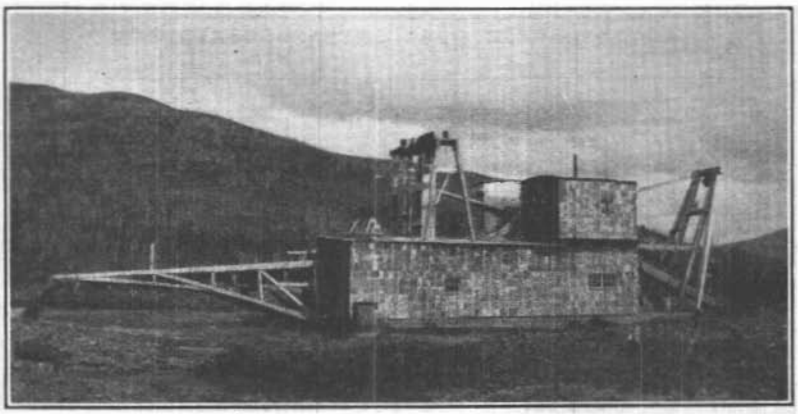


FIGURE 57.—The 2½-cubic foot distillate-driven flume dredge on Yankee Creek

up to 12 and 15 feet and is limited by the disposal of tailing. For satisfactory operation the gravel and bedrock must permit easy digging and free sluicing (see figs. 56, 57, and 58).

Additional details of Alaska gold dredges

Dredge No.	Operator	Bucket line		Anchorage	Revolving screens		Pumps		Stacker or conveyer	
		Number	Dumping per minute		Dimensions, feet	Perforations, inches	Size of discharge, inches	Normal gallons, water per minute	Length, feet	Belt width, inches
1	Alaska Dredging Association	31	18	Lines	None		10	3,000	None.	
2	Alaska Investment & Development Co	32	14	Spuds	4 by 21	3/8, 1/2, 3/4	8	1,750		24
3	Alaska Kougarok Co	31	15	Lines	4 by 24	3/8, 1	10	3,000	68	24
4	Alaska Mines Corporation	74	27	Spuds	6 by 20	1/4, 5/8	12	4,500	70	22
5	Bangor Dredging Co	86	22	do	5 by 23	3/8, 5/8, 1 1/4	10	3,000		
6	Bering Dredging Corporation	54	24	Lines	4 by 21	2 1/2	7 and 10	3,600	45	24
7	Candle Creek Dredging Co	52	27	Spuds	None		14	4,000	None.	
8	Casadepaga Mining Syndicate	30		do	None		12	4,500	None.	
9	Crooked Creek Dredge	29	16	Spud	None		10	3,000	None.	
10	Dexter Creek Dredging Co	34	12	Spuds	4 by 24	3/8, 1	10	3,000		
11	Dime Creek Dredging Co	29	19	do	None; shaking		6	900	None.	
12	Eskimo Gold Mining Co	64	21	do	1, 7 by 12; 1, 7 1/2 by 12.	3/8, 1 1/2	5 and 10		80	30
13	Hammon Consolidated Goldfields Co. No. 1	103	22	do	7 by 40	3/8, 1/2, 1 1/2	2, 12; 2, 6; 1, 4	12,000	160	36
14	Hammon Consolidated Goldfields Co. No. 2	82	22	do	7 by 40	3/8, 1/2, 1 1/2	2, 12; 2, 6; 1, 4	12,000	142	36
15	Hammon Consolidated Goldfields Co. No. 3	103		do	7 by 40	3/8, 1/2, 1 1/2	2, 12; 2, 6; 1, 4	12,000	160	36
16	Iverson & Johnson	27	18	Lines	None		8	1,600	None.	
17	Luther Gold Dredging Co		16	Spuds	4 by 21		12	3,600		
18	Northern Light Mining Co	30	16	do	None		5 and 10	3,600	None.	
19	Shovel Creek Dredging Co	52	21	do	None		8		None.	
20	Swanson Creek Mining Co				None					
21	Wild Goose Mining Trading Co. No. 1	63	22	Spuds	4 1/3 by 22	1/2, 3/8 to 1 1/8	10	3,000	60	28
22	Wild Goose Mining Trading Co. No. 2	55	21	Spud	Shaking	3/8, 1/2	[a] 5 and 10	3,600	60	28
23	Cache Creek Dredging Co	66	18	do	6 by 12	8	5 and 15	6,000	None.	
24	Berry Dredging Co	57	25	Spuds	4 by 15	2	8 and 12	4,200	68	24
25	Fairbanks Gold Dredging Co. No. 1	79	24	do	5 by 24	1/2, 3/4, 1	6 and 10	4,000	90	
26	Fairbanks Gold Dredging Co. No. 2 [b]	38	13	Lines	3 by 22	1/2, 5/8, 1	12	3,600	72	24
27	Chatham Gold Dredging Co	60	33	do	None		8	1,500	None.	
28	Riley Investment Co	54	22	Spuds	4 by 14	2 1/2	8 and 12	4,500	68	24
29	Northern Alaska Dredging Co	54	24	Spud-lines	4 by 14	2 1/2	8 and 10		42	24
30	Flume Dredge Co	29	12	Spuds	None		12	4,000	None.	
31	do			do	None		12	4,000	None.	
32	Innoko Dredging Co	59	28	do	4 1/2 by 19	1, 2 1/2	8 and 12	5,000	60	18
33	Guinan & Ames Dredging Corporation	31	15	Spud	4 by 16	1, 1/4	8	1,800	75	14
34	Kuskokwim Dredging Co. [b]	72	17	do	6 by 20	1/2, 3/4	3 and 10	3,600	80	24

Dredge No.	Operator	Table and sluice data			Riffles [d]	Save-all area, square feet	Approximate total weight of dredge, tons	Size of hull, feet	Original builder
		Flume dimensions, feet	Gold-saving area, square feet [c]	Grade of flume or main tables					
1	Alaska Dredging Association	3 by 70	210	10 inches to 12 feet	Rail		68	24 by 44 by 4⅓	Union Construction Co.
2	Alaska Investment & Development Co		525	1¼ inches to 1 foot	Rail and SH	17	145	30 by 60 by 5½	Do.
3	Alaska Kougarok Co							34 by 60 by 5½	Risdon Iron Works.
4	Alaska Mines Corporation		580	1¼ inches to 1 foot	AI	20		38 by 74 by 5½	([e]).
5	Bangor Dredging Co		500	1½ inches to 1 foot	do	36	325	36 by 92 by 6¼	Union Construction Co.
6	Bering Dredging Corporation	3 by 80		¾ inch to 1 foot	Rail		135	30 by 60 by 5½	Do.
7	Candle Creek Dredging Co	3½ by 72	248	10 inches to 12 feet	do			30 by 62 by 5	Do.
8	Casadepaga Mining Syndicate	3 by 70	210 UC		do		125	28 by 60 by 5	Kimball & Saupe.
9	Crooked Creek Dredge	2½ by 60		10 inches to 12 feet	do	20		28 by 50 by 3½	([e]).
10	Dexter Creek Dredging Co		200	1¼ inches to 1 foot	SH	32		30 by 60	Union Construction Co.
11	Dime Creek Dredging Co	1½ by 54	81	9 inches to 12 feet	Rail		55	18 by 37 by 3	([e]).
12	Eskimo Gold Mining Co		755	1¾ inches to 1 foot	SH	40		44½ by 86 by 7	Western Engine Co.
13	Hammon Consolidated Goldfields Co. No. 1		4,000	1¼ inches to 1 foot	do		1,750	56 by 140 by 11½	Yuba Manufacturing Co.
14	Hammon Consolidated Goldfields Co. No. 2		4,000	1¼ inches to 1 foot	do		1,500	56 by 115 by 11½	Do.
15	Hammon Consolidated Goldfields Co. No. 3		4,000	1¼ inches to 1 foot	do		1,750		Do.
16	Iverson & Johnson	2 by 60	UC	12 inches to 12 feet	Rail		55	25 by 50 by 3	([e]).
17	Luther Gold Dredging Co		UC					30 by 60 by 5½	Union Construction Co.
18	Northern Light Mining Co	3 by 80	240	12 inches to 12 feet	Rail		160	28 by 60 by 5½	Union Iron Works.
19	Shovel Creek Dredging Co	2⅔ by 78	208	12 inches to 12 feet	do			30 by 60 by 5	Yuba Manufacturing Co.[e]
20	Swanson Creek Mining Co							30 by 60	B. Bernard.
21	Wild Goose Mining & Trading Co. No. 1		612	1 inch to 1 foot	SH	36	360	36 by 75 by 6½	Yuba Manufacturing Co.
22	Wild Goose Mining & Trading Co. No. 2	4 by 20	492	1 inch to 1 foot	SH and AI			32 by 96	I. B. Hammond.[e]
23	Cache Creek Dredging Co	4 by 108	432	10 inches to 12 feet	Rail and MnL	90		55 by 87 by 7⅔	Bucyrus.[e]
24	Berry Dredging Co	2, 2½ by 66	340	10 inches to 12 feet	AI and MnG	28	250	40 by 66 by 5½	Union Construction Co.
25	Fairbanks Gold Dredging Co. No. 1		730	1¼ inches to 1 foot	AI	21	350	40 by 90 by 6	Do.
26	Fairbanks Gold Dredging Co. No. 2 [b]		298	1½ inches to 1 foot	AI and SH	26		38 by 90 by 5	Risdon Iron Works.[e]
27	Chatham Gold Dredging Co	2½ by 60	150 UC	1 inch to 1 foot	Rail		75	22½ by 46 by 4	Holbrook, et al.
28	Riley Investment Co	3½ by 75	264	1 inch to 1 foot	MnG, rail, AI	26	140	30 by 62½ by 5½	Union Construction Co.
29	Northern Alaska Dredging Co	3 by 75	225	1 inch to 1 foot	Rail and AI	26		30 by 60 by 5½	Do.
30	Flume Dredge Co	2½ by 74	185 UC	10 inches to 12 feet	Rail		125	28 by 60 by 4	Kimball & Saube.
31	do	2½ by 74	185 UC	10 inches to 12 feet	do		125	28 by 60 by 4	Do.
32	Innoko Dredging Co	2, 2½ by 75	465	18 inches to 12 feet	AI and CI	45	260	38 by 73½ by 5	Union Construction Co.
33	Guinan & Ames Dredging Corporation	2½ by 75	187	10 inches to 12 feet	CI	30	115	26 by 50 by 4⅓	Do.
34	Kuskokwim Dredging Co.[b]	None	560	1 and 1¼ inches to 1 foot.	AI	30	350	36 by 90 by 6⅓	Do.

[a] 10-inch sand pump.
[b] Sand elevator.
[c] Riffled area exclusive of save-all or undercurrent; UC, undercurrent.
[d] SH, steel or iron shod Hungarian riffles; AI, angle-iron Hungarian riffles; MnL, manganese-plate shod longitudinal riffles; MnG, manganese grate riffles; CI, cast-iron riffles.
[e] Dredge reconstructed.

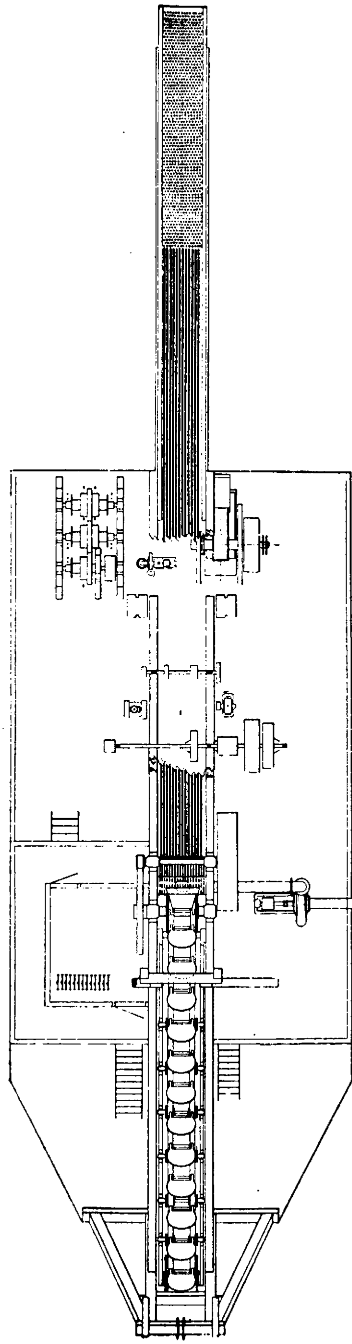


FIGURE 58.—Plan of 2½-cubic foot distillate-driven flume dredge with undercurrent

FLUME-TYPE DREDGE WITH REVOLVING SCREEN

The flume-type dredge with revolving screen is an improvement over the single-sluice dredge. The dredge at Cache Creek (see No. 23, in table, and fig. 59) is working shallow gravels with many

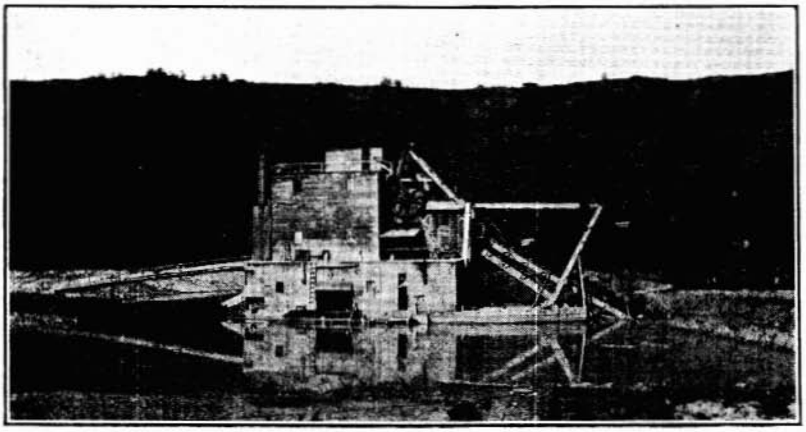


FIGURE 59.—Electrically driven 6½-cubic foot screen-flume dredge on Cache Creek

large bowlders and some clay. The buckets deliver to the revolving screen. At the lower end of the screen are three high-pressure 1¾-inch nozzles for disintegrating the material. The oversize (over 8

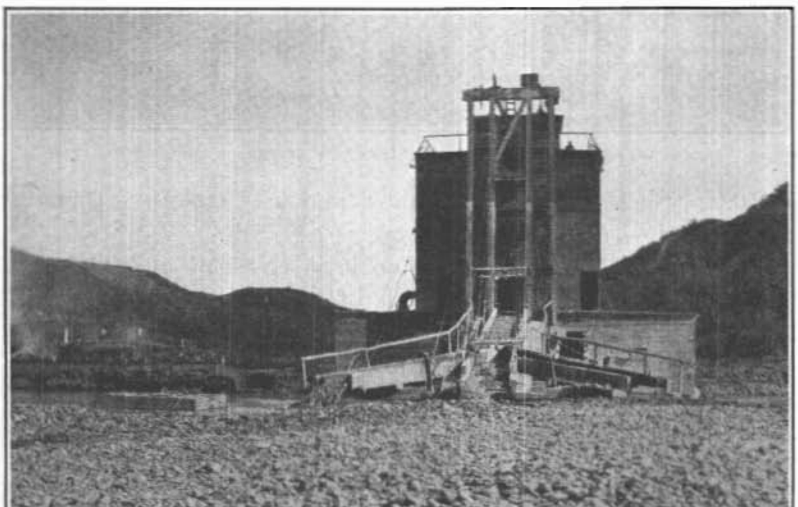


FIGURE 60.—Flume of the Cache Creek dredge

inches) passes through a chute which has two outlets and is dumped 10 feet astern. The undersize goes to the head of the riffled flume. The lowest 20 feet of this flume is divided into three branches, and by shifting the flow from one to the other the tailing is dumped level across the series of cuts. With these arrangements the gold saving is greatly improved, the sands are prevented from running back under the dredge, and the water level in the pond can be better maintained (fig. 60).

COMBINATION-TYPE DREDGE

For average Alaska dredging conditions, where the gravels are not more than about 20 feet deep or not too shallow for proper flotation, the combination type of dredge with revolving screen, flume, and conveyer is, in general, better adapted than other types. The material is disintegrated on the coarse-mesh screen with water under pressure, the oversize going to a belt conveyer and the undersize to the flume. The conveyer is really a fixed stacker (figs. 61

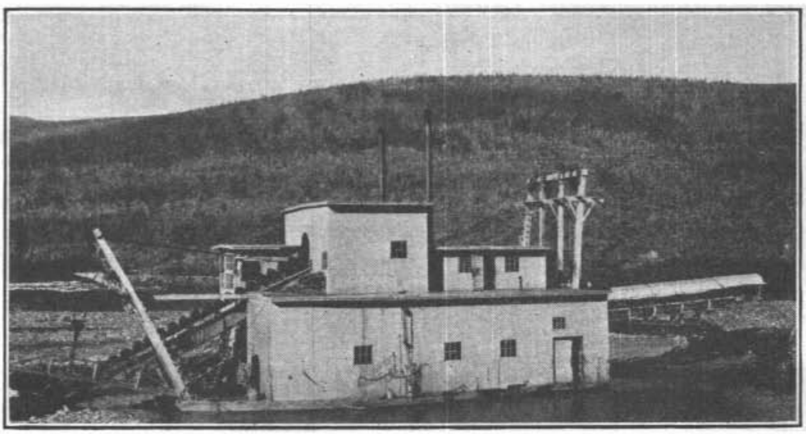


FIGURE 61.—Steam-driven combination-type dredge on Mammoth Creek

and 62). Such dredges are lighter and less expensive than table-stacker dredges of similar capacity.

Two dredges of the combination type (Nos. 24 and 32 in table) have two flumes, one at either side of the screen and conveyer (fig. 63). The undersize from the screen drops onto a short, wide, riffled sluice set on a steep angle, then passes onto another sluice set in the reverse direction, and is distributed to the two flumes. These two dredges have more than double the gold-saving area of the dredges with single flumes and in many respects are quite similar to the table-stacker dredge.

The conveyer on the combination dredge stacks the heavy material where it is most needed. Thus, when the deposit contains much fine material, the flume is extended beyond the end of the conveyer. The heavy material from the conveyer then prevents the fine material from the flume from running back under the boat. Should the dredge have only one flume, the conveyer is installed at one side or over it. To maintain the pond, if the gravel contains little clay or

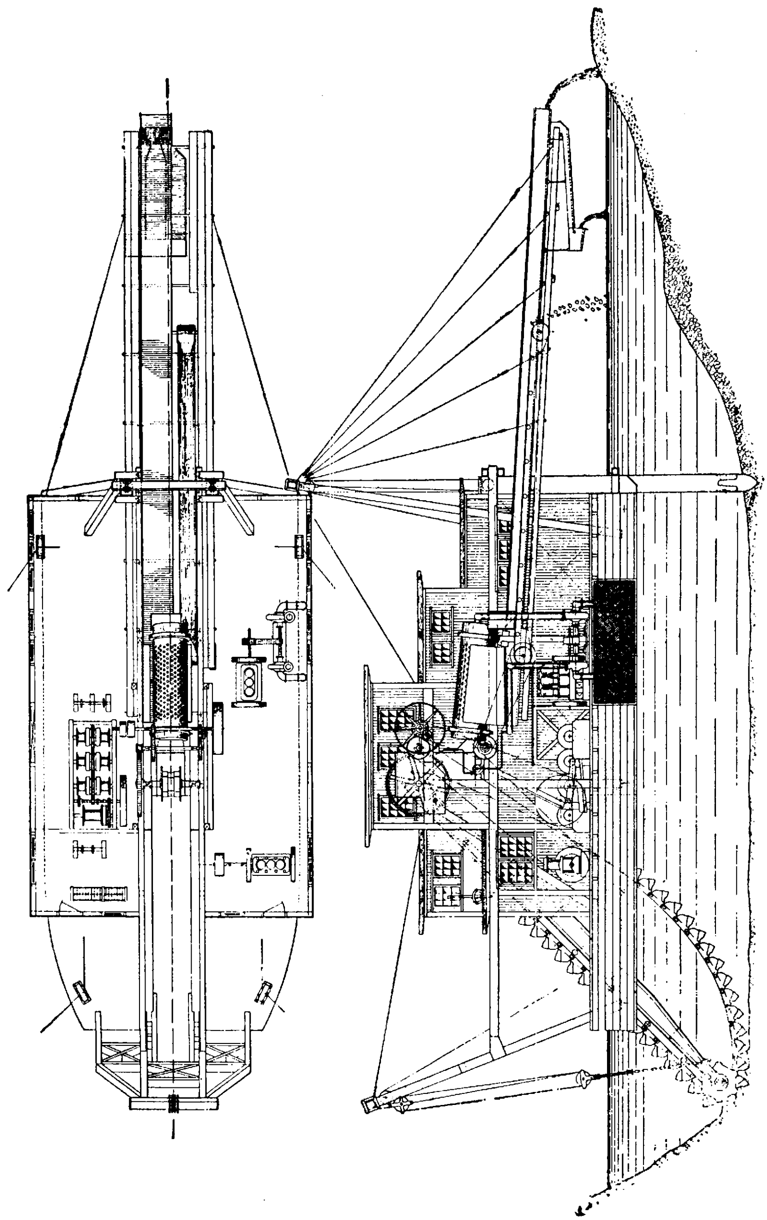


FIGURE 62.—Plan and elevation of 3 ½-cubic foot combination-type dredge with revolving screen, flume, and conveyer and equipped with undercurrent

fine material, the conveyer is extended beyond the end of the flume, so that the fine material is backed by the coarse gravel.

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STACKER-TYPE DREDGE

The stacker or California type dredge has the widest field of usefulness of any of the dredges. It is the best dredge for gold that is

FIGURE 63.—Conveyer and two flumes on the Berry dredge

difficult to save and is the only dredge satisfactory for the more difficult and deep deposits. The buckets deliver to a revolving screen with perforations generally not more than 1 inch in diameter.

IGURE 64.—The 3½-cubic foot semi-Diesel-driven stacker dredge on Candle Creek in the Kuskokwim

After disintegration and washing, the oversize is stacked behind the dredge, the undersize is distributed to the gold-saving tables and sluices, and the tailing is discharged astern (figs. 64 and 65).

Two dredges of this type (see Tables 12 and 22) are equipped with shaking screens made in two sections, timed to work in opposite directions. The motion is imparted by eccentrics, and on the No. 12 dredge was 124 three-inch strokes per minute. The screens are equipped with bars, and cast-iron "fingers" suspended over them retard and help disintegrate the material, which is washed by jets of water under high pressure. The oversize, which may still include some unwashed clayey material, goes to the stacker, the undersize falls on riffled chutes and is distributed to the tables, and the tailing is discharged through sluices astern of the dredge. An extra man must be employed as a screen and flume tender.

Dredges 26 and 34 were both digging downstream, and to keep back the sand were equipped with sand elevators. The tailing from the tables is delivered to a sump and thence is elevated by the sand

FIGURE 65.—No. 1 dredge of Hammon Consolidated Goldfields Co., at Nome; a 9-cubic foot electrically operated stacker dredge

buckets into a chute, which delivers it to the stacker. No. 26 has one elevator and No. 34 has two, one for each set of tables. Few dredges on the creeks experience difficulty with sand unless they are digging downstream. In fact, several dredges have to deliver tailing to provide anchorage for the spuds.

In addition to the water required for stripping or thawing, plenty must be available for floating and sluicing. For the average Alaska dredge not less than 35 to 50 miner's inches of clear water should flow constantly into the pond, otherwise the pond water will become too thick, causing excessive wear of the pumps and interfering with the gold saving. For some dredges larger quantities may be required. The straight flume type requires more water for sluicing than dredges of similar capacities with screens. Except in dry seasons the local creek supply is generally ample for dredging purposes.

DETAILS OF DREDGE CONSTRUCTION

It is not practicable to discuss the many details of dredge design, construction, and operation; the reader is referred to the various books and articles on this subject. Special reference should be made to " Gold Dredging in the United States," by Charles Janin, published as Bureau of Mines Bulletin 127. Some of the principal features which apply especially to dredging in Alaska are, however, mentioned below.

HULLS

Many of the hulls made for use in Alaska were too small, as shown by the number that have been extended and widened or have pontoons added to increase buoyancy. Smaller dredges have used

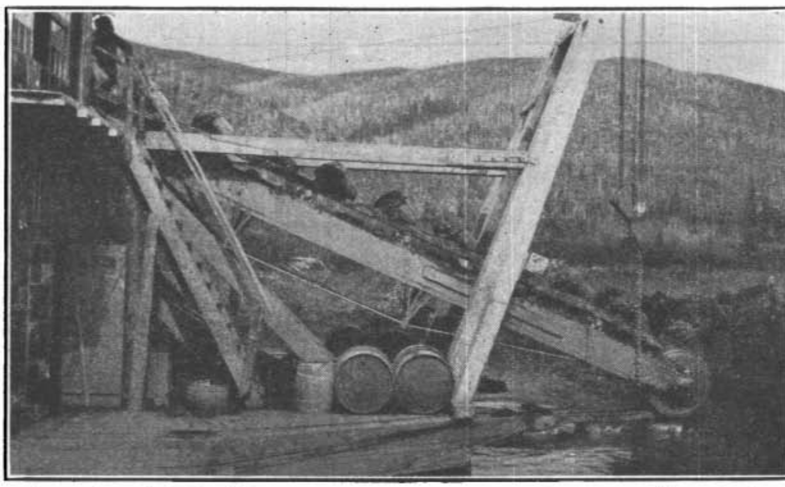

FIGURE 66.—A light $2\frac{1}{2}$-cubic foot open-connected bucket line on flume dredge

empty oil drums for this purpose. Wooden hulls are used exclusively; the large dredges recently constructed at Nome have steel framework. With reasonable care, a hull should last the life of the property. One hull is still in fair condition after 20 seasons of dredging. Native timber makes very poor hulls.

BUCKET LINES

Most of the smaller dredges have open-connected bucket lines (fig. 66). Their main advantages are lighter weight and lower power requirements, and at one time they were favored for digging difficult bedrock and bowlders. The advantage of the modern close-connected line is so marked that comparison is hardly necessary. The shape and weight of the buckets are determined mainly by the character and depth of the ground and the size of the gravel. For tight, hard-digging ground a smaller, strongly built bucket should be used. Ground with bowlders requires larger buckets (fig. 67). For clayey ground the buckets should be wide, shallow, and free from inside projections so their load can be more easily dumped. With a strong, properly designed manganese-steel bucket line and enough power, practically any unfrozen bedrock in Alaska dredging fields can be satisfactorily dug. Dredge 21 on Ophir Creek has dug 10 feet of slabby limestone bedrock with no great difficulty. Except on some of the smaller flume dredges, most of the ladder trusses are equipped with chutes or pans to catch the spill from the buckets and return it to the digging face. During freezing weather steam or hot water run down this chute helps to keep the material from freezing to the ladder. In discharging into the screen hopper

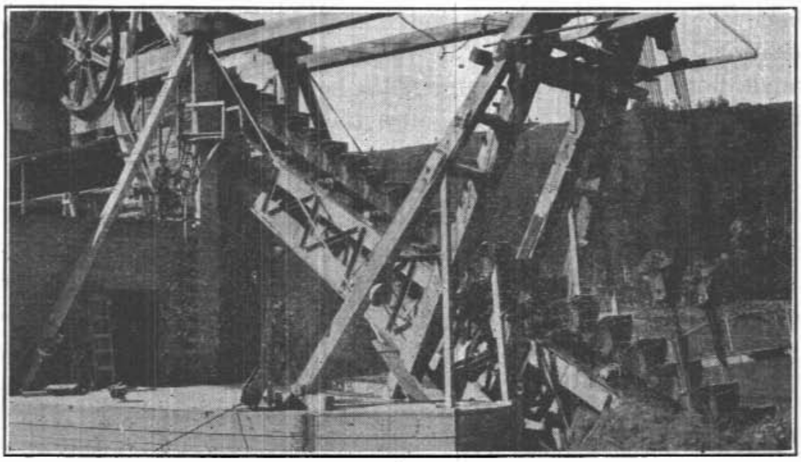

FIGURE 67.—A 6½-cubic foot close-connected bucket line of special design

or flume the buckets also spill some material, which falls onto a steeply inclined grizzly in the well hole, the undersize going to the save-all sluices.

Upper and lower tumblers of various shapes are used on the older dredges. The newer and the modernized dredges are mostly equipped with a round lower tumbler and a five or six sided upper tumbler. Except on the larger dredges and several other stacker dredges, the main bucket line is driven by a single bull gear. This subjects the shaft to severe strains, and has caused many breaks of the shaft or gear. The double-gear drive equalizes this strain and improves the working of the bucket line.

Lack of enough power for the bucket line is sometimes due to having the engine which drives the bucket line also drive other equipment. One dredge in interior Alaska has recently increased its daily capacity by about 300 cubic yards by changing a pump drive to the other engine. The speed of the bucket line should be readily adjustable to suit different digging conditions. The variable-speed motor on electric dredges answers this requirement most successfully.

The buckets and lips last three to five or more seasons of average digging, for the yardage handled during a season is relatively small. Frozen ground causes the most wear and requires much additional power. At a mine recently worked at Nome all the bucket lips on one of the large dredges had to be replaced after one season's digging in partly thawed ground.

EFFECT OF DIGGING CONDITIONS

High bedrock gradients increase the difficulties of operation and seriously affect the operating cost. Dams must be constructed to raise the level of the water in the pond, and in the shallower ground much additional bedrock must be dug to provide enough draft. A dredge should not dig downstream unless the conditions are not a handicap. It generally means working against the "lay" or gravel flow, especially if the gravel is flat and shingled. Downstream work usually necessitates the building of dams unless the gradient is very low, complicates tailing disposal, and makes digging more difficult.

One dredge in the interior started at the head of the creek, working downstream on a 7½ per cent grade. Digging conditions were generally bad, including numerous bowlders to be disposed of; moreover, dams had to be constructed across the narrow channel about every 40 feet of advance. The cost of the dams alone is stated to have amounted to about 60 cents for every cubic yard of ground dredged. Although the grade has now decreased to about 2 per cent and dams are no longer necessary, digging from that direction is more difficult. The dredge averages only about 60 per cent of the yardage that one of this size will normally handle, partly due to the reasons stated and partly to the fact that much clay is present, which also slows down washing.

LENGTH OF DREDGING SEASON

The dredging season in Alaska normally lasts three to five months. On the Seward Peninsula it averages about 100 days, most of the dredges starting in June and closing in October. A number work 120 to 145 days during a favorable season, others about half this time. One of the large dredges at Nome started July 6, 1923, and operated until December 2, or 149 days; and another started on May 1, 1924, and continued to December 7, or 220 days, which establishes a new record for Alaska. In 1912 and 1915 the Blue Goose, which then had steam power, ran for 162 days on Ophir Creek.

Starting is generally delayed on creeks fed by springs, as the successive overflows build up thick ice known as "glacier" ice, which generally covers the entire valley. In the spring of 1922 the ice on Shovel Creek was over 15 feet thick; it virtually covered the dredge and caused serious damage. On July 13, 5 feet of this ice still remained, and dredging was not possible until August, when further difficulties were encountered because of the seasonal frost. The average season on this creek is about 75 days.

The dredging season in the interior averages 130 to 165 days, from early in May or June to late in October or early in November. The record is 194 days, attained by one of the Otter Creek dredges in 1916. In 1923 the Kuskokwim dredge and the Cache Creek dredge each ran 174 days.

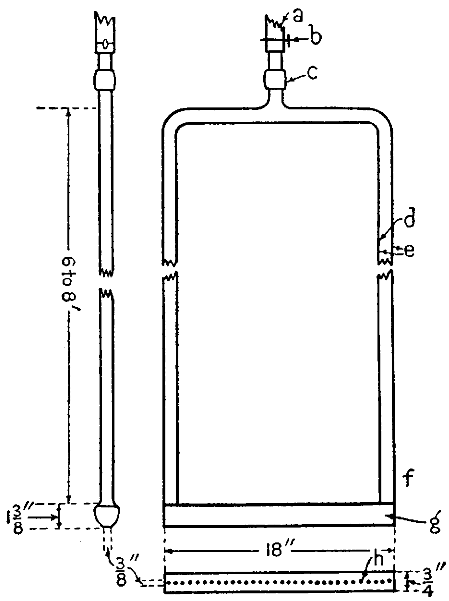

FIGURE 68.—Steam ice cutter, 120 pounds pressure: *a*, Steam hose; *b*, hose clamp; *c*, sleeve; *d*, ½-inch gas pipe; *e*, asbestos tape insulation, outer steel casing; *f*, brazed connection; *g*, 1-inch outside diameter brass tubing; *h*, $\frac{1}{32}$-inch holes

ICE

In the fall the ice as it forms is broken and pushed aside by the dredge, or the cakes are removed. Slush and anchor ice, however, quickly close on the dredge and soon freeze it in tightly. There is no practical way of combating this kind of ice, although heating the hulls or the pond water with steam has been tried. Experienced operators know that when thick ice starts to form the end of the season is at hand, and the dredge should be put into winter quarters. Some dredges continue to dig until frozen in and are left until spring. This practice may leave the dredge unprotected from early spring floods and other dangers. The better procedure is to stop early enough to dig a level bench at some protected place and lower the water, letting the dredge rest on an even bottom. Dredges are only removed from the ponds when repairs of the hull become necessary.

In the spring the dredge is cut loose from the ice, water run into the pond, and the dredge floated. The ice in the pond is sometimes cut with saws and axes, but more often with steam points or steam ice cutters. Figure 68 shows one of these ice cutters. The pond ice may also be blasted. For an early start the ice cakes are removed from the pond, and the ground ahead of the dredge is stripped of snow and ice. Where the seasonal frost is shallow, some good results have been obtained by scattering ashes over the ground. Enough ground is thawed ahead with steam, at some operations with water, to get the dredge under way. Experience has shown that the best practice is to start dredging as early as may be practicable in the spring and stop earlier in the fall rather than fight the freezing weather.

HEAT AND LIGHT

The dredges are heated with steam when necessary, generally with a boiler supplied just for this purpose. During freezing weather the stackers and sometimes the flumes are housed in canvas and steam heated. Hot water or steam is applied to the ladder chute, or the line is relieved of the accumulating frozen material from time to time with a steam jet.

Virtually all dredges are lighted by electricity. Daylight is continuous during several summer months. The lighting generator is generally driven by a small auxiliary internal-combustion engine, except on the electric and the steam driven dredges.

OPERATING DATA

Alaska dredges dig 20 to 60 per cent of their theoretical capacity, this wide range being due mainly to the differing efficiency of the various dredges and conditions of operation. An average derived from the performance of all the dredges would be of no practical value, but most dredges working under average conditions realize 40 to 45 per cent of their theoretical capacity. The short dredging season makes it especially imperative that the greatest possible operating time be realized. Many of the dredges work 22 hours daily, sometimes a little longer, for days at a time. The flume dredges often average a longer operating time than other dredges. Some operators claim an average operating time of 90 per cent, which would be possible only under exceptional conditions, but the running time should average 75 to 85 per cent of the total time available. The principal causes of lost time are engine or power trouble, mechanical accidents, floods, lack of water, frozen ground, stepping ahead or moving in shallow ground, and clean-ups.

The following table shows the causes and the amount of time lost by two dredges operated under widely differing physical conditions; further data are given under "Dredging costs."

Lost time in percentage of total time

Cause of delay	Wild Goose dredge No. 1 [a]		Cache Creek dredge, 1922
	1919	1920 [b]	
	Per cent	*Per cent*	
Step ahead	2.57	2.84	
Moving to cuts	.91	.96	1.72
Moving lines	1.47	2.12	.56
Rocks	1.52	2.93	.28
Clean-up	.04	.02	1.09
Sluices	.03	.02	.19
Stacker	.52	.21	
Repairs, machinery	1.47	1.42	
Engine trouble	.32	.22	
Bucket line, ladder	2.57	1.53	1.18
Screen	.12	.09	.35
Winches	.25	.23	.26
Pumps	.03	.10	.15
Electric equipment	.35	1.27	.42
Spuds	.05	.11	.05
Frost		.48	
Pond and dam	2.66	1.03	
Miscellaneous	.65	.36	[c] 18.20
Lower tumbler, oiling			.07
Upper tumbler, repairs			.21
Power plant, ditch, etc			.71
Hopper			.16
Lost time ... per cent	15.53	15.94	25.60
Do ... hours	335.42	409.25	1,063.03
Running time ... do	1,824.58	2,158.75	3,088.97
Total time ... do	2,160.00	2,568.00	4,152.00

[a] Digging downstream.
[b] Time lost in 1917 was 34.9 per cent.
[c] Time lost on account of floods, pond, and ditch trouble.

Most dredges are operated on 12-hour shifts, the shore men, stripping and thawing crews, and others that may be required working 10 hours. Several companies have adopted the eight-hour shift. On account of the short season and the increased wage, dredge men usually prefer the longer shift. The average shift on the dredges comprises one winch man, one engineer, and an oiler, with one or two shore men or roustabouts on the day shift. Most companies employ a dredge master as superintendent. On distillate-driven flume dredges the engineer spends about half his time with the engines and may also act as oiler and flume tender. In all, five men constitute the entire crew for steady operation on the smallest flume dredges.

WAGES

The wages paid by the dredging companies vary widely, even in the same districts. The following is the average scale; board and lodging is provided in addition. The shore men and other laborers are paid the prevailing wages, as given in the section on "Labor."

Dredge wages

	Winch men	Engineers	Oilers	Dredge master
Seward Peninsula	$7.50–$9.00	$8.00–$9.00	$6.00–$7.50	$10.00–$12.00
Interior:				
Iditarod-Innoko	8.00– 9.00	7.50	7.00– 7.50	12.00– 13.00
Innoko (eight hours)	7.50	7.50	6.50	
Fairbanks	8.00	8.00	7.00	[a]275.00–300.00
Circle	9.00	9.00	6.50	
Yentna (eight hours)	6.00	[a, b] 225.00	5.00	[a] 225.00

[a] Per month. [b] Electrician.

Dredge masters, winch men, and engineers living in the United States or elsewhere out of the district are generally given traveling expenses both ways and receive wages only when on the property.

POWER COSTS

The table on Alaska dredges shows the power used and the amount of gasoline, distillate, fuel oil, Diesel oil, or wood fuel consumed by the dredges in an average working-day. The cost of power on distillate-driven dredges and dredges in isolated districts, where cheap fuel or hydroelectric power is not obtainable, is generally the greatest single item of the operating cost. Two companies operate their electric shore plants with Diesel engines; both are located close to tidewater. Two dredges are operated by hydroelectric power, and one of the companies in the Innoko district (fig. 1, *22*) is now installing a hydroelectric plant. In most districts there is little opportunity for developing reliable and economical water power. The Wild Goose Co. had available for power use the ditch and pipe line from former hydraulic operations. This water power is available for about 100 days each season, and an auxiliary distillate engine aboard the dredge is used when the water fails. Although climatic conditions at Cache Creek would permit the use of water for power during the entire season, the head is low, and during an unusually dry season there may be a month or so when lack of water seriously affects the operation of the power plant.

The Diesel engine has greatly reduced power costs and will receive greater attention for dredge power in future.

Steam is the ideal power for the average Alaska dredge but should not be installed unless there is an abundant supply of good wood or coal near by. Early steam dredges had old and inefficient steam equipment, which consumed large amounts of fuel. As the wood supply soon had to be hauled long distances, the power costs became prohibitive, necessitating a change in power generation. Locomobile-type steam equipment is the most practical and economical dredge power in those isolated districts where wood can be obtained at reasonable cost.

The Berry dredge is equipped with two 75-horsepower locomobiles which have given satisfactory service. For power purposes they consumed an average of 4 cords of wood per operating day. An additional half cord of wood is consumed during the spring and fall, when the dredge must be heated. The wood now costs $15 per cord on the dredge. At $60 per day for wood and $23 for the wages and board of two engineers, one on each shift, this daily power cost is $83, or $0.554 per horsepower-day. On a basis of 2,200 cubic yards dredged per day, this amounts to $0.038 per cubic yard.

The following table has been compiled from data on 11 dredges operated on the Seward Peninsula in 1921, and shows that the cost of power is exceptionally high on the distillate and semi-Diesel dredges.

Dredge power cost, Seward Peninsula, 1921

Number of dredges	Kind of power	Cubic yards dredged in season	Total horse-power	Cost of power [a]		
				Per day	Per cubic yard dredged	Percentage of operating cost
5	Distillate	309,700	320	$441.00	$0.142	48.6
4	Semi-Diesel	475,250	342	331.50	.069	33.1
1	Diesel-electric	278,000	200	87.75	.034	20.0
1	Hydroelectric	[b] 2,020	140	50.00	.025	12.9
11			1,002	910.25		
Average		[b] 12,470			.73	33.8

[a] Includes only cost of fuel, lubricating oil, and labor in attendance. At most of the distillate-driven dredges the engineer devotes only part of his time to the engines.
[b] Per day.

The average cost of distillate delivered to the above dredges was 63 cents per gallon. The 24° Diesel oil at the semi-Diesel dredges cost 36 cents per gallon and at the Diesel-electric plant 30 cents. Distillate cost 17 cents and 24° Diesel oil 6⅜ cents per gallon at Seattle. The charge of $50 per day at the hydroelectric plant includes the proportional cost of ditch maintenance and attendance at the plant, the latter being mainly part of the dredge master's wages, all prorated on the basis of 100 days for the season.

CACHE CREEK DREDGE

Until 1921 the Cache Creek dredge was steam operated, and a poor-grade lignite coal mined close by was used for fuel. The coal proved unsatisfactory, the steam power too costly, and with the heavy steam equipment aboard the dredge drew too much water for proper draft. Hydroelectric power was then developed, a 1-mile ditch being constructed to deliver the water through a double pipe line 1,800 feet long and 34 inches in diameter to a 23-inch double-discharge turbine water wheel under 85-foot head. The 300 kv. a. belt-driven generator produces the alternating current, which is transmitted at 11,000 volts to the transformer near the dredge, where it is stepped down to 2,300 volts and transformed to 440 volts aboard the dredge. An average of 3,800 kw. h. is used per operating day. In 1922 power, which included ditch and pipe-line maintenance and the cost of labor, supplies, and power-plant repairs, cost $0.0168 per kilowatt-hour, or $0.0283 per cubic yard dredged. The average cost of this power for three seasons has been $52.43 per day, or $0.0258 per cubic yard dredged. The pipe line, turbine, and most of the electrical equipment was secondhand. The entire power installation cost $52,634, including $19,473 for the ditch and pipe line and $10,078 for the dredge electrical equipment.

DREDGING AT NOME

The largest power plant for dredge operation in Alaska is at Nome and has six 525-horsepower Diesel engines. These use 14 to 16° fuel oil, delivered to the Nome anchorage in tank steamers. The fuel consumption under average load is approximately 25 gallons per hour per engine. The engines are direct connected to 2,300-volt alternating-current generators. This current is transformed to 11,000 volts and transmitted 3½ miles to the dredges. Conditions are also favorable for developing cheap power from coal or Diesel oil in the Fairbanks district, where the plant can be located close to the Alaska Railroad.

METHODS OF ESTIMATING YARDAGE DREDGED

Methods of estimating the volume of ground dredged vary. A number of the smaller operators roughly measure the area dredged at the end of the season and, knowing the average depth dredged, can approximate the yardage. Several operators dredging shallow deposits use the unit, "square feet of bedrock dredged," but also state the average depth dug during the season. The more systematic operators make a survey every two weeks, or each month, recording the area in square feet, the average depth in feet, and the volume in cubic yards. Allowance is made for the slope of the banks and irregularities in the slope or depth of the cut, especially in the deeper ground.

A method used by a number of the companies is to lay out a base line along one or both sides of the course to be dredged, setting stakes at intervals of 100 or more feet. From these points the survey is made, then plotted, and the area obtained with a planimeter, or calculated. From the area and the average depth of ground dug, derived from the daily dredge reports, the yardage is determined. The area ahead of the dredge is often staked out in 100-foot or other size squares. With either method the position and progress of the dredge and the cut measurements can be quickly determined. In ground where the distribution of gold is irregular or prospecting has not been thorough, close drilling may be done ahead of the dredge. The course to be followed by the dredge and the depth of the bedrock to be dug are further ascertained by frequently panning the material dug, and unprofitable areas can thus be avoided.

GOLD CONTENT OF GROUND DREDGED

The average recovery of gold per cubic yard dredged in Alaska each season from 1911 to 1922 was 51 to 77 cents per cubic yard, according to Brooks.[45] In 1923 this average dropped to 40 cents, the lowest in history. Most of the gold gravels now being dredged yield 20 to 50 cents per cubic yard, about one-third averaging around 50 cents. Three dredges report gold recoveries of 60 to 75 cents per cubic yard and one more than $1.25. There appears to be small opportunity of acquiring dredgeable ground which will exceed 40 to 50 cents per cubic yard unless new virgin fields should be discovered.

DREDGE OPERATING COSTS

Alaska dredging costs are usually high and vary widely, as the dredges differ in size and efficiency and work under widely differing conditions. Moreover, the operating cost for the same dredge may vary greatly from season to season. This report gives the operating cost only, and unless otherwise noted does not include depreciation, depletion, royalty, interest, or other charges against capital invested.

The operating cost is 15 to 35 cents per cubic yard. The higher figure has sometimes been exceeded, due to unusually adverse conditions, serious accidents, or inefficient management. Costs of 15 to 18 cents are only realized by a few well-managed properties in the more accessible districts under generally favorable conditions. Some of the low costs claimed are often due to the bookkeeping system employed or to the fact that office expense, management, etc. are not included. From incomplete data supplied by operators of 11 dredges running under widely differing conditions on the Seward Peninsula in 1921, an attempt has been made to estimate the cost of dredging for that year. The data cover operation of

[45] Brooks, A. H., and Capps, S. R., "The Alaskan mining industry in 1922"; Mineral Resources of Alaska, 1922; U. S. Geol. Survey Bull. 755, 1924, p. 15.

four dredges in the Nome districts, three in the Solomon district, and four in the Council district. With the exception of a very small yardage which was artificially thawed at two of the places, the ground dredged was unfrozen, except for some seasonal frost. The 11 dredges dug 1,323,500 cubic yards, but 740,000 cubic yards of this were handled by three dredges.

The operating costs were 15 to 38 cents per cubic yard, the average being 21.6 cents. The total amount of capital invested in dredging equipment was estimated at $590,000. This is low, but a number of these dredges were acquired for nominal sums and could not now be replaced for twice the amount. Although the life of the property usually could not be definitely determined, the depreciation on equipment roughly averaged 4.64 cents and simple interest at 6 per cent averaged 2.67 cents, a total of 7.31 cents per cubic yard; at the various mines it ranged from 2 to 20 cents. In this estimate the cost of land, royalties, etc., are not included. The season of 1921 was longer than the average season and operating conditions were generally more favorable. The number of days worked by the dredges varied from 75 to 129, the average being about 100.

One engineer estimates that the frozen ground on the Nome tundra can be dredged at an operating cost of 9 to 10 cents per cubic yard, exclusive of thawing costs. The total cost, including thawing and all capital charges, is estimated at 23 cents per cubic yard. The estimate is based on the assumption that four dredges are operated for a season of seven months and are capable of digging 800,000 cubic yards per month.

DETAILED DATA FROM INDIVIDUAL OPERATIONS

The following detailed data and costs cover operations conducted by dredges of different sizes and types under differing conditions. Much of the information obtained concerning production and capital charges of mining operations, and in some instances the operating costs, is confidential and must be omitted. It is particularly gratifying to be able to present complete costs for the Wild Goose Mining & Trading Co.'s No. 1 dredge, which were freely given, for these data contain detailed accounts of its very successful operation from 1910, when it started, to the shutdown in 1924. This dredge was formerly driven by distillate engines. In 1915 it was electrically equipped and operated by hydroelectric power, except during the late fall or during short periods of water shortage, when power was supplied by the auxiliary distillate engine.

Operations of Wild Goose dredge No. 1

[Total cubic yards dredged, 1910–1924, inclusive, 3,023,774]

Year	Length of season	Operating time	Dredged— Per season	Dredged— Per day	Average value recovered per cubic yard	Operating cost per cubic yard
	Days	*Per cent*	*Cubic yards*	*Cubic yards*		*Cents*
1910			12,550		$1.7013	[a] 53.67
1911	135.6	68.4	223,719	1,649	.8573	[a] 20.90
1912	128.5	72.4	224,490	1,917	.3992	[a] 21.25
1913	126.5	75.0	197,793	1,563	.6207	[a] 31.77
1914	124.5	89.2	272,403	2,188	.7666	[a] 15.34
1915	123.2	84.9	265,393	2,154	.7189	[a] 15.75
1916			229,876			[a] 19.81
1917	143	65.1	215,730	1,509	.5559	24.00
1918			149,503		.7617	[b] 29.45
1919	90	84.5	164,224	1,825	.8164	[b] 29.91
1920	107	84.1	217,347	2,031	.6938	21.81
1921	129		260,548	2,020	.7146	19.34
1922	111	87.7	229,984	2,072	.9390	17.47
1923	108	84.7	201,455	1,865	.6718	18.48
1924	77	90.1	158,759	2,062	.4701	18.51

[a] Exclusive of management, which amounts to from 2.2 to 4 cents per cubic yard.
[b] Difficulty with frozen ground conditions. Retarded digging.

NOTE.—Before 1920 some small areas were thawed. Ground usually contained only seasonal frost. Depth dug varied from 7 to 24 feet. Bedrock was schist and thin-bedded limestone. Gravel was medium size with some bowlders. Dredge was digging downstream.

Operating costs of Wild Goose dredge No. 1

	1917	1918	1919	1920
Labor and mess	$13,725.10	$7,660.37	$8,081.50	$10,746.00
Repairs and renewals	12,551.75	14,438.62	11,188.52	9,777.56
Distillate and oil	9,455.47	4,357.32	2,151.20	1,366.96
Supplies	1,925.92	2,349.98	4,009.67	1,645.32
Freight on supplies	1,525.32	1,326.26	1,712.12	1,385.27
General expense	1,914.26	1,802.45	1,915.19	2,104.16
Stable	4,031.92	2,645.53	4,424.82	3,444.91
Ditch	1,402.66	2,087.01	3,052.05	4,288.25
Dams			2,382.39	1,230.80
Camp installation			721.60	1,292.55
Bullion charges	218.68	297.21	346.65	416.38
Insurance		1,750.00	3,361.91	2,456.93
Management, etc	4,654.95	4,900.83	5,037.80	6,196.96
Traveling expense	315.25	408.55	744.40	1,057.01
Total	51,784.28	44,024.14	49,129.82	47,409.46
Per cubic yard	.240	.2945	.2991	.2181

NOTE.—Capital invested in dredge and its equipment, $125,000; in power plant, $15,000. Depreciation and interest, 6 per cent; amounts to $18,876 per season, or $0.07 to $0.126 per cubic yard (estimated).

Operations of Wild Goose dredge No. 2

Year	Length of season, days	Cubic yards dredged— Per season	Cubic yards dredged— Per day	Average value per cubic yard, cents	Operating cost per cubic yard, cents
1921	137	203,257	1,479	36.81	21.01
1922	100	213,797	2,138	24.47	17.79
1923	91	150,303	1,652	53.66	17.74

NOTE.—Cost includes management, etc. Former Blue Goose dredge purchased by Wild Goose Co. for $15,000; operated by them for three years only; shaft broke late in 1923; operation finished; ground condition similar to No. 1 dredge but digging was upstream.

Riley Investment Co., dredging costs and data, Otter Creek

	1921	1922
Operating costs:		
Dredge operation, renewals, and repairs	$35,851.79	[a] $40,066.27
Ground sluicing, brushing, etc	6,441.49	1,219.90
Insurance	768.00	768.00
Expense account, including management	7,827.47	6,638.55
Thawing	59,572.10	32,651.92
	110,460.85	
Credit (profit from machine shop) [b]	7,542.00	
Total	102,918.85	81,374.64
Per square foot of bedrock ... cents	33.2	17.4
Per cubic yard [c] ... do	61.8	33.6
Operating data:		
Square feet of bedrock dug	309,475	465,950
Average depth dug ... feet	14.5	14.0
Cubic yards dug [c]	166,200	241,604
Square feet of bedrock thawed [d]	260,000	265,000
Thawing cost—		
Per square foot ... cents	23.0	12.5
Per cubic yard ... do	42.5	23.7
Per square foot dredged ... do	19.2	7.0
Per cubic yard dredged [c] ... do	35.8	13.5
Average value of gold recovered per cubic yard [c] ... do	61.4	54.2
Number of operating days [e]	[f] 161	[g] 163

[a] Cost of raising sunken dredge, $7,475, not included. Includes $6,372.84 for new buckets, lips, etc.
[b] Overcharge made against dredge and thawing; credited later.
[c] Cubic yard value, cost, and other data calculated from square foot data.
[d] Of ground thawed, approximately half was thawed with steam and half with water.
[e] Includes about 20 days lost due to labor strike.
[f] May 25 to Oct. 28.
[g] May 25 to Nov. 4.

NOTE.—Dredge was constructed in 1914. In 1923 this dredge operated a season of 162 days, digging 488,675 square feet, or 271,486 cubic yards. The average depth dug was 15 feet. About two-thirds of the ground dredged was frozen and was thawed with water at natural temperature. The operating cost was 25.1 cents per cubic yard.

Beaton & Donnelly dredge data, Otter Creek [a]

	1920	1921	1922
Operating cost:			
Dredge preliminary	$6,328.53	$9,645.85	$4,442.71
Dredge operation	29,441.44	32,768.74	31,858.96
Expense account	2,183.55	2,566.29	2,188.41
Preliminary stripping	3,595.00	1,947.15	7,417.00
Mess account loss			2,301.93
Ditch repair	1,522.20		
Dredge repairs			1,108.85
Preliminary thawing	644.31	698.40	
Thawing operations	32,371.79	6,419.05	330.90
Total [b]	76,086.82	54,045.48	49,648.76
Cost per square foot of bedrock ... cents	14.5	11.8	11.3
Cost per cubic yard ... do	28.9	23.7	21.8
Operating data:			
Bedrock dug ... square feet	525,000	456,300	439,200
Average depth dug ... feet	13.5	13.5	14.0
Cubic yards dug	262,500	228,150	227,733
Bedrock thawed ... square feet	[c] 235,000	Small area.	Very little.
Number of operating days	[d] 187	[e] 142	[f] 161

[a] Dredge constructed in 1916. Since 1923 operated by Northern Alaska Dredging Co.
[b] No management charged. Would add 1.5 to 2 cents per cubic yard.
[c] In 1920 about one-half of ground thawed was thawed by steam, balance with water.
[d] May 7 to Nov. 9.
[e] June 15 to Nov. 3.
[f] May 21 to Oct. 28. Lost eight days due to broken shaft.

NOTE.—Cubic yard data calculated from square foot data.

Cache Creek dredge data

	1921	1922	1923	1924
Operating cost:				
Labor, salaries, management, etc.	$15,653.08	$49,656.07	$37,539.78	$40,794.37
Dredge and power supplies	7,167.34	12,543.20	8,038.31	23,118.39
Miscellaneous [a]	3,991.34	8,830.19	12,632.13	9,100.62
San Francisco office, etc.	908.06	645.00	875.62	([b])
Total	27,722.82	71,674.46	59,085.84	73,013.38
Per cubic yard ....cents	0.1458	0.1799	0.1921	0.3246
Operating data:				
Working days	[c] 94	[d] 173	[e] 174	[f] 151
Digging time ....per cent	73.0	74.4	76.0	83.0
Lost time ....do	27.0	[g] 25.6	[h] 24.0	[i] 17.0
Cubic yards dug	190,155	398,323	307,044	224,897
Average depth dug ....feet	9.0	8.6	9.4	8.7

[a] Includes bullion charges, insurance, traveling expense, sundries, etc.
[b] Office expense, etc., included above.
[c] July 24 to Oct. 25.
[d] May 17 to Nov. 5.
[e] May 13 to Nov. 3.
[f] May 13 to Oct. 11.
[g] Floods caused four shutdowns, with loss of 31½ days.
[h] During August operated only half of time due to water shortage for hydroelectric power; nine days lost through floods.
[i] Broken spud caused loss of 12 days.

NOTE.—Unfrozen shallow creek deposit, gravels medium size with numerous bowlders in certain areas; must dig up to about 6 feet of easy-digging coal formation bedrock to provide dredge flotation; digging upstream over average grade of about 2.5 per cent.

Berry dredge data

	1922	1923	1924
Operating cost:			
Labor and superintendence	[a] $20,903.08	[b] $25,733.42	[c] $25,444.06
Supplies, etc.	[a] 15,062.66	[b] 13,709.57	14,632.34
Office expense	562.61	474.44	469.32
General expense	2,138.99	773.94	2,075.78
Traveling expenses	1,324.97	1,153.83	1,581.14
Insurance and taxes	2,652.05	2,541.68	2,956.04
Total	42,614.36	44,386.88	47,158.68
Per cubic yard ....cents	0.2279	0.1764	0.3302
Operating data:			
Days operated	[d] 92	[e] 125	[f] 99
Operating time ....per cent	84.4	80.2	----------
Cubic yards dug	187,132	251,692	142,841

[a] Includes stripping and thawing labor, $3,991.15; supplies, cost not segregated; steam thawed, 40,000 cubic yards.
[b] Includes stripping and thawing labor, $6,750.74; supplies, $571.05; stripped 76,000 cubic yards of overburden for natural thawing.
[c] Includes stripping and thawing labor, $8,716.44; stripped 86,000 cubic yards of overburden.
[d] July 2 to 18, July 30 to Oct. 12. Shut down July 19 to 29 to thaw ahead of dredge.
[e] June 20 to Oct. 23.
[f] July 1 to Oct. 7. Includes about 20 days—July 12 to Aug. 1—when dredge was shut down, lacking water for floating.

NOTE.—Cost of prospecting labor and supplies in 1923, $1,904.76, not included in above cost. Moving and reconstruction of dredge completed June, 1922 (cost $13,267.42) and charged to capital account. Steam-operated dredge; ground partly frozen, mostly seasonal frost; from 5 to 18 feet deep after stripping off 4 feet of overburden; average depth, 10 feet; bedrock, schist, and granite; some high, hard reefs; large granite bowlders now.

Alaska Mines Co., Nome, dredging costs, 1920

	Operating cost	Cost per cubic yard dredged	Per cent of operating cost
		Cents	
Labor, dredge only	$9,525.89		
Material, dredge	383.89		
Repairs, labor and material	1,914.51		
Miscellaneous	1,362.65		
Total	13,186.94	6.73	24.4
Thawing	10,195.00	5.20	19.0
Power	30,598.00	15.61	56.6
Total operating	53,979.94	27.54	100.0
Overhead	11,423.00	5.83	
Total	65,402.94	33.37	

This 8-cubic foot electric-driven dredge was formerly operated at Nome. It dug 196,000 cubic yards in 1920, of which 25,290 cubic yards were old tailing. During the 100 days the dredge operated the actual running time was 79 per cent, the greatest loss of time being due to lack of oil for power. Power was produced by a 650-kilowatt shore plant at a cost of 6.5 cents per kilowatt hour, which was excessive. Of the ground dredged, 88,807 cubic yards were thawed with water at natural temperature at a cost of 11.49 cents per cubic yard.

TYPICAL PLACER IN INTERIOR DISTRICT

The following will illustrate the operation of a 2½-cubic foot, distillate-engine driven, flume dredge in an isolated interior district. In 1922, the second season of its operation, this dredge dug 136,000 cubic yards from June 3 to October 22, or 142 days, averaging about 20 hours of digging time each day. The average depth dug was 11 feet. The ground was unfrozen, but for some seasonal frost, and afforded favorable digging conditions. The operating costs for 1922 were:

Operating costs for distillate-driven flume dredge

	Total	Per cubic yard
Labor	$14,973.54	
Mess	3,807.41	
Mining material	540.40	
Distillate and oil	10,769.65	
Express and postage	800.50	
Traveling expenses and miscellaneous	866.50	
	31,757.91	$0.2335
Management, San Francisco office expense, etc	6,081.16	.0447
	37,839.07	.2782

The capital invested in the dredge is $42,706; depreciation in eight years plus 6 per cent simple interest amounts to 5.8 cents per cubic yard dredged in 1922. Dredges of this type and size were formerly operated on the Seward Peninsula at an operating cost of about 15 cents per cubic yard.

COST OF GOLD DREDGES

The cost of the gold dredges has increased 50 to 70 per cent since 8 or 10 years ago. As formerly mentioned, some of the earlier Alaska dredges could not be duplicated and placed in operation now for twice the original cost. Although it is difficult to estimate the cost and capacity of a dredge unless all conditions are known, the following table, compiled from data obtained from several dredge builders, gives the weight, approximate average monthly capacity, and other details for dredges of different sizes and types and their approximate cost f. o. b. Pacific coast.

Approximate cost and weight of gold dredges

Type of dredge	Size of bucket	Type of bucket	Average monthly capacity	Kind of power	Approximate horsepower	Digging depth	Lumber in hull	Total weight of dredge	Approximate cost f. o. b. San Francisco
	Cubic feet		*Cubic yards*			*Ft.*	*Board feet*	*Tons*	
Flume	1¼	Open	17,500	Distillate	30	12	17,000	52	[a]$15,000
Combination flume screen and conveyer	2	Close connected.	36,000	Steam locomobile	80	30	75,000	210	48,000
Do	2	Close	36,000	do	75	20			45,000
Flume	2½	Open	30,000	Distillate	60	18	60,000	125	24,500
Screen and stacker	3	Close	45,000	Diesel engine	100	20	80,000		62,000
Do	3½	do	52,000	do	150	35	105,000	325	86,000
Do	3½	do	52,000	do	150	20			75,000
Combination flume screen and conveyer.	4	do	60,000	Steam locomobile	150	35	105,000	345	82,000
Screen and stacker	4	do	60,000	Diesel engine	220	35			100,000
Do	5	do	85,000	Steam electric	250	40	200,000	670	200,000
Do	6	do	100,000	do	300	40	220,000	[b]875	215,000
Do	7½	do	120,000	do	400	40	250,000	825	235,000

[a] Cost of machinery only.
[b] Includes steam shore plant.

NOTE.—Full Diesel engine power costs $1,000 to $1,500 more than steam-locomobile power on 3 to 3½ cubic foot dredges.

From a study of the preceding table and the tables on ocean and inland freighting costs an approximate estimate can be made of the cost of a dredge landed at the property. To this must be added the cost of erection. Under average conditions, 2½-cubic foot flume dredges have been erected for $7,000 to $9,000, the combination 3½-cubic foot dredges for $12,000 to $18,000, and the 3½ to 4 cubic foot stacker dredges from $18,000 to $25,000. Dredge 32 (see table on Alaska dredges, p. 178) was recently erected in 43 days at a cost of $15,000.

SPECIMEN COSTS

Dredge 2[45a] ready to operate cost $50,000 in 1911. Dredge 5, as originally erected on Bangor Creek in 1914, cost $127,000. It cost $90,000 in Oakland. Dredge 6 cost $85,000 erected in 1915. About 10 years ago a 2½-cubic foot flume dredge similar to dredge 8, cost about $27,500, erected in the Council and Solomon districts. These dredges, erected in districts of average accessibility, would now cost $45,000 to $50,000. Although the cost of the large dredges is not definitely known, dredge 13 cost about $500,000 erected and dredge 14 about $600,000. Their erection was completed during the winter when extremely cold weather added greatly to the cost. Dredge 21, as now constructed, cost about $125,000. Dredge 24 cost $86,000 erected in 1915. Dredge 25 cost $135,000 at Oakland in 1917 and erected at the property $180,000. Dredge 28 cost $80,000 erected. Dredge 30 cost $50,000 in 1921. Dredge 33, as originally erected on Glacier Creek, cost $28,000 in 1915. Dredge 34 cost $112,000 erected in 1918, but an additional sum has been spent in changes made later. Many dredges on Seward Peninsula have changed ownership at least once or twice and have often been acquired for very nominal costs through direct sale or bankruptcy proceedings. Others have been constructed with parts from older dredges.

MOVEMENT OF DREDGES

Some dredges which have proved unprofitable or which have completed the dredging of their original ground have been moved to new locations. These used dredges have at times been acquired for a small part of their original cost or have been amortized during their earlier period of operation, and thus made it possible afterward to dredge lower-grade gravels or smaller areas which could not otherwise be worked at a profit. This is typical of a number of the dredging operations, particularly on the Seward Peninsula.

Dredges have been moved to new localities on the same creek, to distant creeks, and often to new districts. Some small dredges on Seward Peninsula weighing from 125 to 200 tons have been moved over the snow without dismantling; dredges weighing 250 to 400 tons must be dismantled, and the hull is cut in half, lengthwise. During the winter of 1921 dredge 5 was moved from Bangor Creek to Anvil Creek, a distance of 14 miles. The dredge was dismantled and the hull cut in two lengthwise. The dismantling cost $4,500, the hauling $11,000. The entire job, including the re-erection of the dredge, was contracted for at $28,000. In 1916 dredge 18 was moved from Mystery Creek to Ophir Creek, a distance of 12 miles. The dredge was dismantled and the hull cut in half. The contract cost of dismantling and rebuilding the dredge was

[45a] Dredge numbers refer to first column of table facing p. 178.

$3,000, and the cost of moving was $3,000. The dredge ready to operate on Ophir Creek cost the company $28,500. Dredge 24 was dismantled and hauled 2½ miles down the creek for $3,500 and reconstructed. This entire cost was about $15,000, which included additional material. Several dredges have dug their way for several miles downstream through old tailing to a new area, the gold recovery by the dredge paying a part of the moving cost.

GOLD SAVING

The high cost of placer mining in Alaska and the lower average gold content of the gravels now being mined necessitate efficient gold-saving equipment. At most mines the gold is chiefly coarse or heavy, and although some fine gold is generally present, practically all can usually be saved with very few refinements in gold-saving practice if the gold-bearing material is thoroughly washed and disintegrated. Quite often the gold is coated with a film of iron oxide or with some compound of sulphur, arsenic, or other impurity. It is difficult to save coated fine gold in the sluices. Light flaky or flour gold is rarely present in appreciable quantity, and only a very small proportion can be saved by usual methods.

The loss of gold in the tailing can not be accurately determined, as there is no practical way of accurately sampling the gold-bearing material or the tailing. The average placer miner does not like to admit that gold is being lost. However, many dumps contain chunks of unwashed material which carry gold and sometimes amalgam. Gold loss in tailing is further evidenced in the number of "snipers" working over old dumps and in the results of drilling or subsequent mining.

Gold losses in the earlier days were probably larger than at present, for the deposits contained a higher gold content, and a loss was not considered so serious. The sluices were often poorly adapted for the work or were overloaded. Purington [46] estimated that in the interior districts where two or five boxes with no drop-offs were used in saving the gold, 10 to 20 per cent of the gold lifted into the boxes was lost. Losses of 50 per cent were not uncommon in those days, and there still are a few mines where only 70 per cent of the gold put into the sluices is recovered.

With free-washing gravel—that is, gravel free of difficult clay—a high percentage of the gold can usually be saved by the customary methods. Most gold losses are accounted for by the presence of stiff sticky clay, which is difficult to disintegrate and tends to rob the riffles of gold or amalgam, and by the lack of suitable sluice

[46] Purington, C. W., Methods and Costs of Gravel and Placer Mining in Alaska: U. S. Geol. Survey Bull. 263, 1905, p. 191.

gradients. Some loss may also result from shortage of water for sluicing; or the intermittent use of water in "splashes," which agitate the riffles, carries gold through the boxes. Lack of grade may prevent employment of added refinements in gold saving at most hydraulic and some open-cut mines; however, refinements in gold saving should be practiced at the drift mines where only the richer part of the deposit is mined and at mechanical or other operations where large amounts of barren or low-grade material are first removed at considerable cost to get to the "pay." Conditions are generally favorable for this at such mines, as the gold-bearing material is elevated and grade thus provided.

Although it is unnecessary here to discuss the refinements of gold saving, certain Alaska methods will be briefly mentioned.

GOLD SAVING IN MINING METHODS OTHER THAN DREDGING

SLUICES

Long sluices are seldom used in Alaska on account of lack of grade. Except where special hydraulic mining methods are employed, sluices more than 200 feet long are used only to aid in disposal of tailing. The longer the sluice the more thoroughly can the material be disintegrated. Narrow sluices and a deep flow of material through them generally cause gold losses, especially if the gold is fine. The flow through the sluices should be deep enough to cover the largest bowlders but under average conditions should not be over 6 or 8 inches. The tendency for the riffles to pack increases with the depth of the flow.

In hydraulic mining, where the material is quite thoroughly disintegrated before it reaches the sluices, short lengths of sluices may prove satisfactory, although if conditions permitted longer sluices and undercurrents would be better practice. In hydraulic mining of creek placers grades of 4 to 6 inches to the 12-foot box are the rule, although higher grades are often created by using special methods of setting the sluice boxes. A grade of 6 inches in 12 feet is generally considered the practicable minimum under average water supply, and higher grades are preferred when available. The sluices should have enough grade to prevent blocking without excessive use of water. At a number of the hydraulic mines a large quantity of ground-sluice water is used because of the low grade available, so the sluices run almost full; yet the gold loss is very slight, for the gold is coarse and heavy, the material is well washed, and the sluices are long.

Fine gold, whether bright or coated, requires special attention. The sluices should be wide, so that the flow may be shallow, and set on steeper grades to keep riffles from packing. The saving of fine gold is best accomplished by separating the heavier material and passing the undersize over gold tables or undercurrents. When the gold is bright, the use of quicksilver is advisable.

In general, 80 to 90 per cent of the average gold recovered is retained either in the dump box, if one is used, or in the first three or four sluice boxes. The lower end of the sluice usually contains only a very small percentage of the total gold recovered.

SLUICE DROPS

Where practicable, vertical drops in the sluice help in disintegrating the material. Although a fall of a few inches will help, the most efficient drop is 1 to 5 or more feet high and is placed where

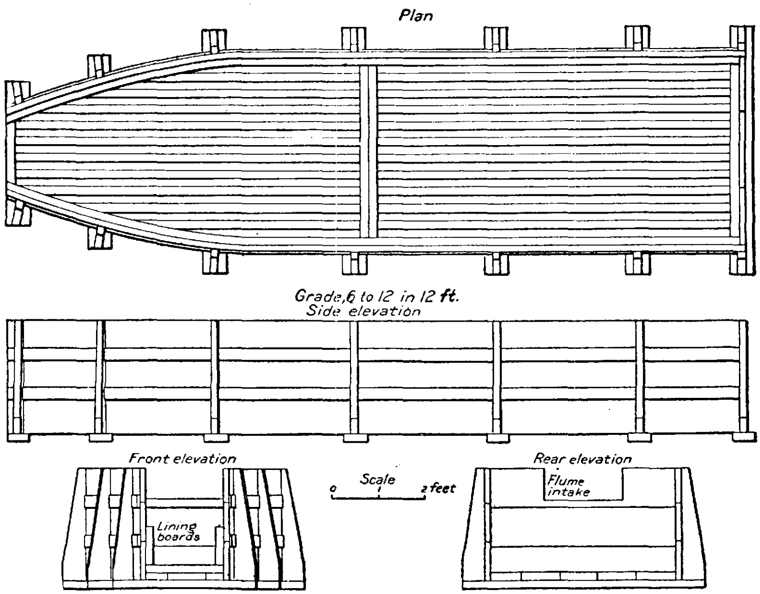

FIGURE 69.—Dump or mud box

the material is first passed over a grizzly or inclined grating. The fine material and water fall into the sluice below, and the washed oversize is dumped outside of the sluice.

MUD OR DUMP BOXES

The use of mud or dump boxes in sluicing is characteristic of drift mining and mechanical mining in Alaska when the material contains clay or mud and is difficult to wash or is delivered intermittently in relatively large loads. Small mud boxes are also used at some placers mined by "shoveling in."

Figure 69 is a sketch of a dump box. The latter is merely a wide sluice box, tapering at the lower end to the width of the regular sluice box and set on a grade of 7 to 14 inches on 12 feet. The box may be paved with pole riffles (usually set lengthwise), with block riffles, or sometimes with steel rails. Where a dump box is used, an extra helper or two may be required to puddle the clayey material, fork out the large rocks, and see that the sluices do not clog. The dump boxes at some mines worked by mechanical methods are 100 feet or more long. Unless the box is of ample size to hold the load properly, it may become clogged and the material on being released booms through the box and sluices, carrying unwashed material to the dump.

RIFFLES

The principal requirements of riffles for Alaska practice are that they be efficient gold savers, cheap but durable, and not too heavy and bulky. However, riffles which are efficient under one set of conditions may not prove suitable under others. The Hungarian or transverse riffle is commonly considered the best, although it retards the flow more than the longitudinal. It is generally good practice to use both, placing the transverse riffles in the upper boxes with the longitudinal below, or alternating with short sets of the transverse. The rolling action of transverse riffles tends to disintegrate the material more readily than the sliding action characteristic of longitudinal ones. The spacing between riffles is regulated by conditions and by the results obtained. At Alaska placers it generally ranges from 1½ to 3 inches; the longitudinal riffles are sometimes given wider spacing.

POLE AND WOODEN-BLOCK RIFFLES

Spruce poles are more generally used in Alaska for making riffles than any other material, especially for the smaller sluices. Pole riffles are cheap and easy to handle but should only be used where the gold is coarse. They are placed longitudinally in the sluices in sets of three to five small green spruce poles 3 to 8 feet long, peeled and held together by nailing them to crosspieces at each end; they are often shod with strips of iron or steel.

Wooden-block riffles are used more at the hydraulic and mechanical operations and are generally made in sets. A number of blocks are set on end with spaces between them and held so by a strip of wood nailed on one or opposite sides. The sets are placed crosswise in the sluice, so that the longitudinal spaces between the blocks are offset or staggered (see fig. 24). The strips should extend beyond the end blocks to allow the liners on the sides of the box to fit over them and hold the riffles in place. Some operators merely "toenail" the blocks to the boxes, but sets properly made are more easily handled and held in place. Spruce and cottonwood blocks are used, but cottonwood makes a poor block.

At one mine the three upper boxes were paved with wooden blocks, with longitudinal rail riffles below. On cleaning up, very little gold was found in the upper boxes, but most of it was found in the rail riffles. The block riffles had been closely spaced and had " broomed " over.

STEEL-RAIL, ANGLE-IRON, AND CAST-IRON RIFFLES

Steel-rail riffles are rapidly replacing wooden blocks, especially where oil rails are obtainable from railroads and other sources at comparatively low cost, but the expense of haulage prevents their use in the more remote localities. Rail riffles answer all requirements for efficient gold savers. The steel rails used weigh 12 to 40 pounds per yard and are placed transversely or longitudinally, usually with the ball side up. When used with the bottom side up, the rails are commonly spaced 1 to 2 inches between edges. It is said that riffles placed bottom side up do not pack, as they cause the proper " boil," and that the gold readily lodges beneath and is protected by the broad flanges. The wide surface of steel exposed when placed longitudinally with the bottom side up lessens the frictional resistance to the flow, which is of advantage where the grade is low. There are numerous kinds of spacers, flanges, and methods of fastening the rails together in sets and for holding them in place in the sluices. Bouery[47] made an extensive study of riffles at the La Grange hydraulic mine in California.

Angle-iron riffles are used mainly on dredges, in some hydraulic elevator sluices, and at a few small open-cut mines. Under favorable conditions they are good savers of fine gold. They should not be used where coarse material is sluiced. The angle irons are set transversely, with the point of the angle usually facing the flow. At several properties in the interior the use of angle irons set at a small inclination improved the " boil " and proved successful. At other mines where angle irons were tried they packed hard and failed, possibly because they were spaced too closely or not set on proper grade.

Cast-iron or manganese grate riffles, some of which are patented, are generally constructed so they can be set either transversely or longitudinally. They are easily handled, are excellent gold savers, and are long-lived, but are too expensive for the average operation. Boiler tubes and old plates from dredge screens are used for riffles at several mines.

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[47] Bouery, P., "A study of riffles for hydraulicking": Eng. and Min. Jour., vol. 95, May 24, 1913, pp. 1055–1060.

STEEL PLATES

Plates of high-carbon steel are sometimes employed. They are elevated above the bottom of the sluice and a transverse space is left between plates, forming a pocket where gold is recovered. This type of riffle is used mainly to save grade and is generally followed by other kinds set at higher grades. The bottoms of the smaller sluices are often lined with boards, so that a space is left between the ends and the sides of the boards where gold can lodge. These are known as "false bottoms," and as they reduce frictional resistance can be set on lower grades, in the same manner as sheet iron or steel is used to line the bottom of unriffled sluices or tail sluices.

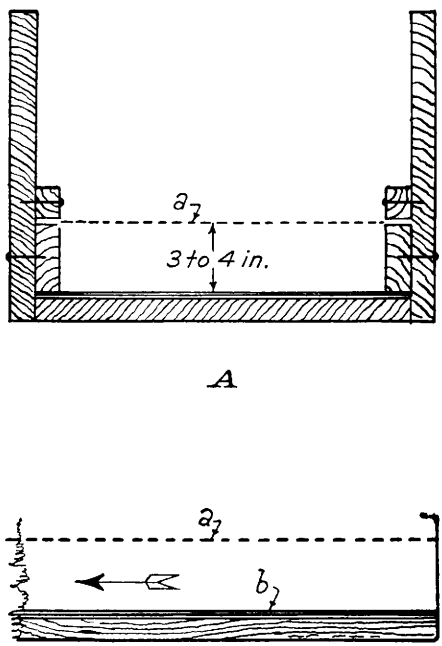

FIGURE 70.—Sluice-box undercurrent. *A*, Cross section: *a*, ¼-inch steel plate, ⅜-inch holes. *B*, Longitudinal section showing riffle and plate: *a*, Perforated plate; *b*, expanded metal screen or wooden cleats over matting, burlap, etc.

ROCK OR COBBLE RIFFLES

Rock or cobble riffles are rarely used. They require steeper grades and, being difficult to lay and take up, are more adapted for tail sluices or others which are cleaned up only after long periods of use.

UNDERCURRENTS AND GOLD TABLES

Undercurrents and gold tables are used for saving fine or coated gold. At many mines their use has been discounted, often for the reason that the small amount of gold recovered by them did not justify the additional attention.

The material should be disintegrated as thoroughly as practicable before it reaches the grizzly or screen. Undercurrents are therefore placed near or at the end of the sluice, and all of the water and undersize should pass through the grizzly to the undercurrent, only the clean oversize being retained and dumped to waste.

A sluice-box undercurrent (fig. 70) is used to good advantage at many smaller operations in interior Alaska. An ordinary sluice box is used, but the last box or two is equipped as shown and usually set at a slightly higher grade than the others. The oversize from the grizzly or plate goes to the dump and the undersize passes over gold-saving blankets of burlap, matting, or other material. The material and arrangement of the blankets depend on the character of the fine gold to be saved. Such undercurrents require cleaning every day or two, as the blankets become slimy with mud. They are removed, washed in a tub, and returned. These undercurrents have been credited with 5 to 20 per cent of the total gold recovered; they save much fine rusty gold. Even better results should be obtainable if conditions would permit these undercurrents to be made wider than the regular sluice and placed on higher grades.

On the Upgrade Association property in the Iditarod district the gold is both coarse and fine, sharp and bright, and some of it is attached to quartz. Plenty of grade is available, as the mines are on the side of a mountain. There are no difficulties with clay. The deposit is hydraulicked, usually with a small intermittent water supply. From 8 to 12 boxes 24 inches wide are set on a 17-inch grade and paved with longitudinal riffles made of 2 by 6 inch timbers shod with pieces of manganese steel 5/8 inch thick and 1½ inches wide. These riffles are spaced 1½ inches apart and held together by a crosspiece similarly shod in sets 6 feet long. One or two boxes may be paved with manganese-steel grids set transversely.

At the end of these boxes is a grizzly of manganese-steel bars set transversely with 3/8-inch spacing, the undersize going through a chute to an undercurrent 4 feet wide and 12 feet long, set on a 34-inch grade. The surface of this undercurrent is covered with cocoa matting, in turn covered with wire screen of ¼-inch mesh. Strips of wood 1 inch thick and 1½ inches wide are fastened transversely to this at 30-inch centers. No mercury is used. The material which continues over the grizzly goes to one box equipped with a sluice-box undercurrent similar to the kind described. The undercurrents at this property have recovered from 5 to 20 per cent of the total clean-up.

GOLD SAVING IN DREDGING

The loss of gold in dredge tailing is usually small if the material is thoroughly washed and disintegrated before it flows over the tables or sluices. The same principles for gold saving hold on dredges as for other methods of placer mining but can, in general, be better applied on a dredge. Although numerous factors enter into the saving of gold, much also depends upon the winch man. Bedrock may not be dug clean or the sluices may be overloaded. Unless the gold is coarse or heavy and the gravel is free of sticky clay there may be a large loss of gold on flume dredges. According to the operator, one flume dredge working a deposit containing much sticky clay was losing about 40 per cent of the gold. Another feature adverse to efficient gold saving on flume dredges is the excessive amount of water generally required to carry heavy material through the flume. The resulting high velocity or deep flow of material does not permit the lighter gold to sink and be caught in the riffles.

RIFFLES

The flumes of these dredges are paved with rail riffles, usually set lengthwise. It would be better practice if some of the rails could be set transversely, particularly in the upper part of the flume, especially if clay is present or the gravel is flat. Material will roll over transverse riffles and be better disintegrated than when it passes over longitudinal riffles, where it tends to slide more than roll. On screen-flume dredges this practice is generally followed, and manganese or cast-iron grate riffles may be used alone or with rails. On the table-stacker dredges standard steel-shod wooden riffles and angle-iron riffles are mostly used. The grades of the main tables average 1 to 1½ inches to the foot.

UNDERCURRENTS

Some flume dredges are provided with undercurrents, and a closely spaced bar or plate grizzly with small openings is installed in the bottom of the flume near its lower end. The material passing through this grizzly is conducted over short tables or sluices paved with screen, expanded metal, or punched plate laid over cocoa matting or burlap; small special transverse riffles and sometimes an amalgamation plate may be used in conjunction. The practical use of these undercurrents is governed by their construction and operation, the character of the deposit, and the character and size of the gold.

One flume dredge, formerly operated in the Council district, reported that 20 per cent of the gold was recovered by the undercurrent. The saving is usually less, and in some dredges the undercurrents have been discarded because of the low recovery. On the Northern Light flume dredge a test made during one clean-up showed that 82.54 per cent of the gold recovered was saved in the upper 25 feet of the flume, 10.93 per cent in the next 30 feet, 3.73 per cent by the undercurrent, and 2.8 per cent in the tail sluice beyond the undercurrent grizzly. This tail sluice was paved with punched screen, ⅝-inch holes, laid over burlap.

SCREENS

Dredges provided with screens not only have the advantage of better washing and disintegration of the material, but by shutting out the heavier stones improve conditions for saving gold. Stiff, sticky clay is always a bugbear to efficient gold saving because of its difficult disintegration and its sluice-robbing propensities. The best means of treating such material is to retain it in the revolving screen until thoroughly disintegrated. The material is rolled over and retarded by bars and rings fitted to the screen and is further retarded and broken up by high-pressure jets from nozzles set at the lower end of the screen. Additional jets may play downward on the material from nozzles projecting from a pipe extending lengthwise through the screen. The action is somewhat similar to that of wet grinding in a ball mill, as the clay is worked over by the gravel until it will pass through the perforations.

If nugget gold is present, the holes in the lower part of the screen are enlarged, and the material passing through them goes to a separate sluice. The nugget sluice on some dredges yields 5 to 25 per cent of the total gold recovered.

SAVE-ALLS AND OTHER APPLIANCES

Save-alls have in virtually every instance more than repaid for their installation and care. All dredges spill more or less material from the buckets, and the gold therein is lost unless a save-all is provided. Many dredges report a saving of $2,500 to $5,000 by the save-all during a working season.

A number of the table-stacker dredges were originally equipped with jigs or other special appliances for recovering fine gold and concentrate, particularly where such gold was coated with iron oxide or other compounds and could not be amalgamated. All of these, except the undercurrents mentioned, have been discarded.

MERCURY

Mercury is not required for saving coarse gold, and rusty or coated gold will not amalgamate. Where fine clean gold is present, the use of mercury in the riffles and undercurrent is essential. It has a strong affinity for clean gold, and the amalgam formed is more readily retained by the riffles and is easier to handle in cleaning up the sluices. Virtually all of the dredges (except small flume dredges where gold is coarse) and many of the larger properties mined by other methods practice amalgamation. There are many other mines, particularly in the interior, where it should be used, as there is generally some fine clean gold present that could be saved by mercury. Many miners, however, want their gold in dust, or wish to avoid the small additional trouble of retorting the amalgam and handling the product.

After a sluice has been used long enough to stop leaks and fill depressions with material the flow is shut off. Then the upper boxes and the undercurrent are charged with mercury, or if much coarse gold is present the mercury may be placed farther down the sluice. More mercury is added from time to time as needed to keep the amalgam dissolved. Some mercury, especially if charged too heavily, will work down from the upper boxes. Proper charging can only be learned by experience. The mercury must be clean and in charging should not be broken in fine globules, which cause heavy loss. Carelessness in the use of mercury may result in increasing the loss of fine gold, but when mercury is properly handled and the sluices are tight and long the loss is negligible. One or two flasks (76.5 pounds per flask) of mercury are generally ample for the needs of the average mine, although much more may be required on a dredge or at a large hydraulic mine.

Amalgamated copper plates are sometimes used in undercurrents or other small sluices, where only sands with fine gold are passed over them. These scour very easily.

CLEAN-UP

SLUICE BOXES

The clean-up of the sluice boxes comprises removing the riffles and collecting the gold dust or amalgam and the heavy concentrates. The interval between clean-ups is generally made as long as practicable to reduce the delay, and depends mainly on the richness of the gravel, the method of mining, condition of the riffles, and financial reasons. Dangers from theft or floods also influence the time of clean-ups. With the richer gravels the dump box, or the first few boxes, may be cleaned every few days, or the head box may be cleaned after each shift, the lower boxes generally being left until the final clean-up. With the leaner gravels cleaning up may be done once a week, once a month, at the end of the mining season, or when the pit is completed.

The flow of water in the sluice is cut down to the proper volume, and the clean-up crew, usually two to four men, including the operator, removes the larger pebbles with forks or other implements. Beginning at the head box, the riffles are lifted and thoroughly cleaned before being removed from the boxes. Two to eight boxes are generally cleaned at a time, some riffles or a stop being left to prevent loss of gold. The material is worked along by stirring with shovels, rakes, or scoops as the flowing water concentrates it. Most of the gold or amalgam lags behind the heavy sand (or concentrates) and is scooped into pans or buckets. The concentrates are worked over and are then shoveled into separate receptacles. The process is repeated until the next lower section is cleaned. All nail holes and crevices are picked clean and the bottom of the boxes swept. Worn-out wooden riffles, lining boards, sluice boxes, and other wooden equipment are burned and the ashes are panned.

The time required for a clean-up generally ranges from a few hours to a shift or two. Special methods are used at some of the mines, and where the sluices are long the clean-up may require a week or so.

DREDGES

Most of the gold recovered by Alaska dredges is recovered in the upper 25 feet of flume, or directly under the screens, or before it reaches the lower half of the tables.

The time of clean-up on dredges varies with the condition of the riffles. Some dredges clean up once a week and others once a month, when usually only the upper half of the flume or the main parts of the tables are cleaned up. The lower sluices are seldom cleaned up until the end of the season. Many dredge operators state that only a few dollars' worth of gold are recovered from the last 5 feet of flume or riffled sluice and feel satisfied that very little gold is being lost. No figures as to the amount of gold lost in tailing are available, but numerous colors of fine gold can often be panned from the washed tailing and both coarse and fine gold from the unwashed clayey material. The regular clean-up takes from a few hours to a shift; advantage is taken of the shutdown to adjust the engines and make minor repairs. One dredge is so arranged that all of the feed can be diverted to one set of tables while the opposite set is being cleaned. However, the possibility of overloading the tables and the difficulty of attending to repairs might outweigh the saving in time.

RECOVERY OF GOLD AND PREPARATION FOR MARKET

CLEANING GOLD DUST OR AMALGAM

The gold dust or amalgam is mixed with more or less sand, scrap iron, and other materials. The larger pieces of foreign material can be picked out by hand and the particles of iron and magnetic sand removed with a magnet. Where mercury is not used, the gold dust is panned and dried, then screened through a nest of screens of different mesh, and foreign particles picked out. The finer dust is cleaned by tossing it into the air with a pan or scoop and blowing off the sand.

Amalgam is softened with an excess of mercury and stirred in buckets or ground in a mortar to bring the base material to the top for removal. The excess mercury is removed from the cleaned amalgam by squeezing through chamois skin, or drill, or other strong cotton cloth.

CLEANING HEAVY SANDS

The heavy material from the sluices and from cleaning the gold dust and the amalgam may contain other metals or minerals besides gold and amalgam, including native copper, silver, platinum, iridosmine, monazite, pyrite, marcasite, hematite, chromite, galena, cinnabar, cassiterite, wolframite, scheelite, barite, and stibnite. In addition, magnetite, ilmenite, rutile, garnet, zircon, tourmaline, and other rock-forming minerals may be present. The specific gravity of some of these minerals is almost as high as that of gold, so that separation by water with ordinary methods is difficult. Where any valuable mineral is present in commercial quantities, the larger bits are usually picked out by hand or roughly concentrated by water. Some of these minerals have been a valuable by-product of gold placer mining; cassiterite has been the main product of several dredges.

Platinum will not amalgamate and when present will be closely mixed with the gold. Although it is as heavy as gold, thin flakes float easily on running water and may not settle with the gold. The black sands from the sluices and from the cleaning of the amalgam should, therefore, be carefully panned. Any platinum spilling over settles to the bottom of the tub and can be panned out later. The gold and the platinum particles are dried; then the platinum can be separated by the blowing process.

At some California gold dredges the platinum is recovered from the tables with the amalgam and the black sands. When the amalgam is cleaned, the platinum separates and sinks to the bottom of the soft amalgam, which is then cleaned by careful panning or blowing, and the sands are passed repeatedly over special pocket or auger-hole riffles and carpet or cocoa matting surfaces.

At some Alaska mines all the heavy sands are panned, rocked, or put over special small sluices. Some fine rusty or coated gold or amalgam ordinarily remains in the sands. It is customary to stir the sands in a tub or vat with cyanide or to put them in a clean-up barrel, add cyanide, lye, or wood ashes, rotate the barrel to brighten the gold, and amalgamate the gold in the barrel. This treatment takes 20 minutes to several hours, after which the sands are panned or passed over special riffles or amalgamated plates. Even then the sands may still contain gold.

All placer concentrates should be analyzed and assayed, for they very often contain large quantities of gold or other valuable minerals or metals that can not be recovered by ordinary methods but may justify their shipment to a smelter.

USE OF CYANIDE

Cyanide is often very carelessly used and when used in solutions of certain strengths will dissolve much gold.

Maclaurin [48] states that the solubility of gold in potassium cyanide is maximum at 0.25 per cent strength, is very slight in solutions containing less than 0.005 per cent, and at 0.01 per cent is 10 times as great as in the 0.005 per cent solution and about one-half as great as in the 0.25 per cent solution. A safe means of using it is to make up a stock solution of 1 ounce of 98 per cent potassium cyanide to ½ gallon of water and then use 4 ounces or about one-half teacup of this solution to 10 gallons of water.

One operator in the interior puts his sands, which are mainly garnet and magnetite, into a tub or box, adds cyanide and mercury, and stirs the mixture for one hour. Then about 80 per cent of the gold is recovered on amalgamation plates; next the sands are heated, dilute sulphuric acid (about 10 per cent strength) is added, and the sands are further heated. They are then treated as before, and virtually all the gold is recovered.

RETORTING AMALGAM

The cleaned amalgam is broken and packed loosely into a pot retort coated inside with clay, chalk, or paper. The retort should not be more than three-quarters full. The cover is provided with an asbestos gasket or luted with clay to assure a tight fit and keyed down. The retort is then placed on its stand and heated by wood, coal, or gasoline. The heat should be raised very gradually, as volatilization of the mercury should not start for about one hour. The mercury fumes are condensed in an iron pipe leading from the top of the retort and fitted with a condenser through which water runs continuously. The mercury is recovered in a vessel containing water. If no condenser is provided, the pipe should be covered with gunny sacking kept thoroughly wet. The retort should be kept at dark-red heat until nearly the end, when the heat is raised to cherry red. This heat is maintained for 15 minutes or so after the last of the mercury has been driven off. The pipe is usually tapped with a hammer to determine whether volatilization is complete.

PRECAUTIONS

The retort is allowed to cool gradually and should not be opened until cold. Care must be taken to do all retorting in a well-ventilated place, with the outlet of the retort kept outdoors, for mercury fumes

[48] Maclaurin, J., "The dissolution of gold in a solution of potassium cyanide": Jour. Chem. Soc. (London), vol. 63, 1893, pp. 724–738; vol. 67, 1895, p. 199.

are very poisonous. The lower end of the retort pipe should not be under water, for a fall in the temperature might create a vacuum, thus drawing water into the retort and causing an explosion. It is safer to hang a piece of sacking over the end and keep it soaking wet.

The small balls of amalgam obtained by the lone miner are often placed on a shovel and held over a fire to drive off the mercury. This should only be done outdoors, and the miner should keep from the fumes.

MELTING RETORT SPONGE INTO BULLION

The retort gold from clean amalgam should be spongy, readily broken up, and a clean golden color. Incompletely retorted amalgam will be light to dark gray, due to the mercury still present. Too high a heat will cause formation of a tough dense mass. Sulphur, arsenic, and other compounds will blacken or otherwise discolor the sponge.

Retort sponge is often shipped to the banks for melting. The larger producers, particularly those in isolated districts, melt it into bullion for safe and easy shipment. A gasoline bullion-furnace is usually used for melting the gold. A graphite crucible is gradually heated and tested, and borax glass is added for flux and melted down. The gold is then added, and as it melts more may be added; the crucible should, however, not be too heavily loaded. The borax glass unites with any iron present and goes into the slag. If much iron pyrite is present, some metallic iron may be added to unite with the sulphur, forming iron sulphide, which comes off with the slag. If much silica is present, soda is added, usually in the proportion of one part of soda to two parts of borax glass. Toward the end of the melt the slag is skimmed off with an iron rod and more borax glass may be added.

When the melt is completed, the crucible is lifted from the furnace and the gold is stirred with a graphite rod and poured into heated bullion molds which have been previously coated by holding them over oil smoke or rubbing with lard oil. The molds should not be too hot but should be hot enough to ignite oil when it is applied to them. The bullion bricks are then plunged into cold water to loosen the slag, or into a pickling bath of one part of nitric acid to three parts of water, which will remove any stain. The bricks are then cleaned with a hammer and a steel slag brush, stamped, weighed, and made ready for shipment.

ASSAYING AND SHIPMENT OF PLACER GOLD

The fineness of Alaska placer gold normally ranges from about $14 to $19 per ounce. While several "runs" of gold on the same creek may differ in fineness and other characteristics, the gold from any particular creek or deposit can usually be easily identified by an expert. The difference in fineness is due mainly to silver alloyed with the gold. Some copper, lead, or other metals may be present. The copper and silver content may be further increased where native copper and silver are present and are not removed in cleaning the dust, as both will amalgamate. Where base material is present, closer assay checks and better settlements will be obtained if the product is divided into clean gold and base bullion.

Some of the highest-grade placer gold has come from the Koyukuk district (fig. 1, *13* and *14*), where gold of 978.5 fineness, or $20.23 per ounce, was found on Fay Creek, and gold of 973.4 fineness, or $20.12 per ounce, on Swift Creek. Some nuggets found on Little Minook Creek in the Rampart district (fig. 1, *31*) were said to assay $20.42 per ounce. Gold dust from Little Moose Creek in the Kantishna district (fig. 1, *27*) assayed only 550 fineness, or $11.37 per ounce, on account of native silver present. On Tenderfoot Creek in the Richardson district (fig. 1, *36*) the gold has a fineness of 640 at the upper end, while at the lower end the fineness is 720. This wide difference may be due to the gold coming from different sources. Fine gold that has been transported relatively long distances from its source is usually purer than coarser gold mined nearer the same source.

The custom of using gold dust in place of money has now passed, except among some of the prospectors, mostly in the Fortymile (fig. 1, *41*) and Koyukuk districts. Gold dust is however purchased by all merchants near the mining camps at a reduction of $1 to $1.50 from its actual value per ounce. Most of the gold dust, retort sponge, and bullion is sent direct to the banks at Nome, Iditarod, Fairbanks, or Anchorage.

The banks conduct their own assay offices, melting all gold received, and settle on the basis of the assay minus a certain deduction for melting, assaying, insurance, express, refining, and marketing. This charge is 2.5 per cent of the gross on amounts under $25,000 and 2 per cent if the amount is $25,000 or more. One bank in an isolated district charges 3 per cent.

The banks ship by express to their representatives in the United States, and the operators not dealing with the local banks ship direct by express or mail. Virtually all of the gold eventually reaches the United States Assay Office at Seattle or the United States Mint at San Francisco. A little goes to the smelters, as does the base bullion. Express rates from virtually any of the camps to Seattle, San Francisco, and other Pacific coast cities normally range from $3.75 to $5 per $1,000 in amounts of $25,000 or more, $4.50 to $5 in amounts less than $25,000, including marine insurance, and in amounts of $1,000 or less are slightly higher. Winter express shipments requiring dog or horse team transportation are practically double the summer rates. Shipments sent by registered first or fourth class mail are limited in weight to 11 pounds. First-class registered mail costs 2 cents per ounce or fraction thereof, in addition to the 10 cents per package for registration fee, with indemnity for loss up to $50. The packages can contain only 3 ounces of gold to be fully covered. Fourth-class mail can be insured up to $100 upon payment of 25 cents in addition to the regular postage.

To allow shipments by registered mail in packages up to 11 pounds in weight, the operator carries a special open insurance policy, which he fills in to cover the shipment, and notifies the insurance company of the details.

ALASKA PLACER-MINING LAW AND TAXATION

An act to supplement the mining laws of the United States in the Territory of Alaska and to repeal an act entitled, "An Act to supplement the mining laws of the United States in their application to the Territory of Alaska; providing for the location and possession of mining claims in Alaska and repealing all acts and parts of acts in conflict herewith to the extent of such conflicts," approved April 30, 1913, was enacted by the Alaska Legislature and approved on April 20, 1915. House Bill No. 48, in chapter 10 of the Session Laws of Alaska, 1915, deals with placer mining, as follows:

PLACER-MINING LAW

SECTION 1. Any person qualified under the laws of the United States who discovers upon the public domain within the Territory of Alaska a placer deposit of gold or other mineral which is subject to entry and patent under the mining laws of the United States may locate a mining claim thereon in the following manner, to wit:

1. He shall post, or write upon the initial post, stake, or monument on the claim, a notice of location containing: (*a*) The name or number of the claim; (*b*) the name of the locator or locators; (*c*) the date of discovery and of posting notice on the claim; and (*d*) the number of feet in length and width of the claim. This notice shall be known as the location notice.

2. He shall distinctly mark the location on the ground so that its boundaries can be readily traced, by placing at each corner or angle thereof substantial stakes, or posts, not less than 3 feet high above the ground and 3 inches in diameter, hewed on 4 sides; or by placing at each corner or angle thereof mounds of earth or rock not less than 3 feet high and 3 feet in diameter and the stakes, posts, or monuments so used must be marked with the name or number of the claim and the designation, by number, of the corner or angle. The initial stake or monument shall be one of the corner stakes, posts, or monuments of the claim located.

If the claim is located on ground that is covered wholly or in part with brush or trees, such brush or trees shall be cut or blazed along the lines of such claim, as to be readily traced.

If located in an open country, the boundary lines shall be located by placing line stakes or line monuments so as to be readily traced from corner to corner of said claim.

SEC. 2. Within 90 days after the discovery and posting of the notice aforesaid, the locator shall record with the recorder of the district wherein such claim is situated, a certificate of location. Such certificate shall contain: (*a*) The name or number of the claim; (*b*) the name of the locator or locators; (*c*) the date of discovery and of posting of the location notice; (*d*) the number of feet in length and width of claim; and (*e*) it shall set forth the description with reference to some natural object, permanent monument, or well-known mining claim, together with a description of the boundaries thereof so far as applied to the numbering of stakes or monuments.

A failure to record a certificate of location of claim as herein provided shall operate as and be deemed abandonment thereof, and the ground so located shall be open to relocation: *Provided,* That if a full compliance with the preceding provisions of this act shall have been made before any location by another, such compliance shall operate to prevent the abandonment or forfeiture of such claim and save the rights of the original locator.

SEC. 3. No association placer-mining claim shall hereafter be located in Alaska in excess of 40 acres, and on every individual or association placer-mining claim located in Alaska after August 1, 1912, and until patent has been issued therefor, not less than $100 worth of labor shall be performed or improvements made during each calendar year, including the year of location for each and every 20 acres or fraction thereof, and where the title of two or more contiguous placer claims has become vested in the same person or persons, or corporation, the said annual assessment work or improvements may be done or made at any place or places on said contiguous placer claims, provided that such work or improvement inures to, and is for the benefit of, the entire area of such placer claims. In computing the value of assessment work or improvements the rate of wages paid in the vicinity for similar work shall be allowed.

SEC. 4. And it is further provided that a survey of the claim or claims by a United States mineral surveyor may be credited to annual assessment work, but in no case shall the credit for such survey and its attendant expense exceed the required assessment for one year on the claim or claims surveyed. When credit is sought for such work or improvement, the claimant must file in the recorder's office in the district in which the claim is situated the field notes of the survey, together with a voucher showing the cost of such survey, properly attested by the surveyor, incorporated into the proof of annual labor as in case of other class of labor or improvements, as provided for in section 7 of this act.

SEC. 5. That no individual placer-mining location hereafter made shall be more than 1,320 feet in its greatest length; and no association placer-mining claim hereafter located shall be more than 2,640 feet in its greatest length.

Any location made containing an excess of ground beyond the limits prescribed in this act, either in area or length, may be relocated as to such excess, but such relocation shall be upon that end of the claim farthest from the initial stake, post, or monument.

SEC. 6. That no power of attorney for the location of placer-mining claims in Alaska shall be valid or have any force or effect whatsoever, nor shall any locations made thereunder be valid or have any force or effect unless such power of attorney be duly executed and acknowledged before an officer authorized to administer oaths and recorded in the office of the recorder for the district in which such claim is located prior to the date of the filing for record of any location thereunder. And no person shall be authorized to act as agent or attorney for the location of placer-mining claims except under written power of attorney duly executed and acknowledged, and no person shall be competent to act as agent or attorney in fact for the location of placer-mining claims for more than one individual in any one recording district during the same calendar month. That no person shall hereafter locate, or cause to be located for himself, more than two placer-mining claims in any one calendar month, in any one recording district, one or both of which locations may be included in association claims.

SEC. 7. In order to hold a claim or claims after the annual assessment work has been done thereon, the owner of such claim or claims, or some other person having knowledge of the facts, shall make and file an affidavit of the performance of such assessment work with the recorder of the district in which such claim or claims is or are located, not later than 90 days after the close of the calendar year in which such work was done, or the improvements made, which affidavit shall set forth the following: (*a*) The name and number of the claim and where situated; (*b*) the number of the days worked and the character and value of the improvements made thereon; (*c*) the date of the performance of such labor and the making of such improvements; (*d*) the place where such work was done and improvements made with reference to the boundaries of such claim; (*e*) at whose instance the work was done and improvements made; (*f*) the actual amount paid for such work and improvements and by whom paid, when such work was not done or improvements made by the owner.

The failure to file for record the proof of assessment work as herein provided shall be deemed an abandonment of the location and the claim shall be subject to relocation by any other person, provided, however, that a compliance with the provisions of this section before any relocation shall operate to save the rights of the original locator, and further provided that if said placer claim or claims have not been relocated by any other person or persons within one year after such forfeiture, the last locator, claimant, or owner of such forfeited claim may return to said forfeited claim or claims and relocate the same as though the same had never been located.

SEC. 8. Any person who shall make or subscribe any affidavit required to be made under the provisions of this act, knowing the statements therein contained, or any of them, to be false, in whole or in part, or without knowing the statements therein contained to be true, shall be deemed guilty of perjury, and upon conviction thereof shall be punished by imprisonment in the penitentiary not less than one year nor more than five years. Any person who shall induce or procure, or shall aid in inducing or procuring another to commit perjury as herein defined, shall be guilty of subornation of perjury and upon conviction thereof shall be punished as herein provided for perjury.

SEC. 9. That any placer-mining claim located or attempted to be located in violation of any of the provisions of this act shall be null and void and revert to the public domain and may be located by any qualified locator as if no such prior attempt had been made.

DUTIES OF MINE INSPECTORS

The Federal and Territorial mine inspectors are empowered by law to have access at all times to any mine and all parts thereof for the purpose of inspecting the workings, timbering, ventilation, means of ingress and egress, and the means adopted and in use for the preservation of the lives and safety of the men employed under ground or on the surface, etc. All mine owners, lessees, agents, operators, managers, or superintendents must render such assistance as may be necessary to enable the inspector to make the examination. Should any mine or part thereof be found to be in an unsafe or insecure condition, or if proper first-aid measures have not been adopted, the inspector shall serve notice in writing, setting forth the nature and place of these defects and requiring them to be remedied within a specified time. The person in charge must immediately notify the mine inspector in the quickest manner possible of any serious or fatal accident. If the inspector can not immediately proceed to the mine, written statements concerning the accident, made and sworn to by those witnessing it, must be procured and must be forwarded to the inspector with a written report. A written report of each minor accident shall be made promptly to the inspector, which shall briefly describe the occurrence and state the number of days the injured person was incapacitated from performing his regular duties.

The Territorial mine inspector shall distribute blank forms requiring statistics of accidents, labor, production, or such other information as the governor may require, which shall be filled in and returned to the mine inspector's office by the person in charge of the mine on or before the 31st day of December each year. The duties and powers of the Territorial mine inspector, the provisions of the acts, etc., are stated in chapter 51, Session Laws of Alaska, 1917; chapter 59, Session Laws of 1919; and chapters 82 and 96, Session Laws of 1923.

TAXATION

A compilation of chapter 31, Session Laws of Alaska, 1921, entitled "An act to establish a system of license taxation, to provide for the collection thereof, and to provide punishment for doing business without a license, and declaring an emergency, as amended by act of May 5, 1923 (ch. 101, Session Laws of 1923)" enacted by the Alaska Legislature, includes, in part, the following as pertaining to mining:

SECTION 1. Any person, firm, or corporation prosecuting, or attempting to prosecute, any of the following lines of business, or who shall employ any of the following appliances, in the Territory of Alaska, shall apply for and obtain a license and pay for said license, for the respective lines of business and appliances, as follows:

* * * * * * *

15. *Mining.*—One per cent of the net income in excess of $10,000 and not in excess of $500,000, and on all net income in excess of $500,000 and not in excess of $1,000,000, 1½ per cent; and on all net income in excess of $1,000,000, 1¾ per cent.

By "net income" is meant the cash value of the output of the mine less operating expenses, repairs and betterments actually made, and royalties actually paid, and all taxes paid under section 2569 of the Compiled Laws of Alaska: *Provided,* That the lessor of any mine operated under a lease shall be deemed to be engaged in mining within the provisions of this act, and the royalties, less the cost of collecting the same, received by him shall be deemed to be the net income within the provisions of this act; but where he receives royalties from more than one mining property he shall pay the tax on the aggregate income over $5.000. No deduction shall be made on account of depreciation of machinery, interest on bonds or money borrowed, or other taxes paid.

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SEC. 2. Every person, firm, or corporation desiring to engage in any of the lines of business * * * as specified in section 1 shall first apply for and obtain from the Territorial treasurer a license so to do. * * *. If the amount of the tax is not a fixed sum (as in placer mining), the applicant shall state in his application that he agrees to pay the license tax and will make a true return and will pay to the treasurer such tax on or before the 15th of the next ensuing January.

Incomes from placer-mining operations, the sale of placer-mining property, etc., are taxable under the Federal income tax law, the provisions of which are so widely known as to require no further mention here.

SELECTED BIBLIOGRAPHY

AUSTRALIA, Annual report, dredging and hydraulic sluicing in Australia in 1914. Melbourne, 1915.

BOUERY, P., Study of riffles for hydraulicking. Eng. and Min. Jour., May 24, 1913, pp. 1055–1060.

BOWIE, A. J., jr., A practical treatise on hydraulic mining. 11 ed., 1910, 313 pp.

BRIGHAM, H. A., Examining and fitting up a hydraulic mine. Eng. and Min. Jour., December 26, 1908, pp. 1257–1260; January 2, 1909, pp. 23–29.

BRITISH COLUMBIA, MINISTER OF MINES, Annual reports. Victoria, British Columbia.

BROOKS, A. H., Placer mining on Seward Peninsula, methods and costs. U. S. Geol. Survey Water Supply Paper 314, 1913, pp. 269–303.

——— Genesis and classification of placers; The gold placers of parts of Seward Peninsula, Alaska. U. S. Geol. Survey Bull. 328, 1908, p. 111.

——— Formation and classification of placers. U. S. Geol. Survey Bull. 592, 1914, p. 27.

——— The Alaska mining industry. Annual reports, U. S. Geol. Survey, Mineral Resources of Alaska.

——— The geography and geology of Alaska. U. S. Geol. Survey Prof. Paper 45, 1906, 327 pp.

BROWNE, R. E., Ancient river beds of the Forest Hill divide. California Min. Bur., 10th Ann. Rept. State Mineralogist, 1890, p. 452.

CANADA, MINISTER OF INTERIOR, Yukon Territory, its history and resources. Ottawa, 1916, p. 76.

DENNIS, F. J., Modern methods of gravel excavation; Steam shovel and dragline excavators. Min. and Sci. Press, August 3, 1922, pp. 136–140.

DUNN, R. L., Drift mining in California. California Min. Bur., 8th Ann. Rept. State Mineralogist, 1888, pp. 736–770.

EDDY, L. H., Bagley scraper for gravel mining in Alaska. Eng. and Min. Jour., August 14, 1915, p. 257.

EDWARDS, W. W., The Klondike pipe line. Eng. and Min. Jour., September 19, 1914, pp. 531–533.

ELLIS, H. I., Prospecting methods at Fairbanks. Eng. and Min. Jour., May 8, 1915, p. 805.

——— Development methods at Fairbanks. Eng. and Min. Jour., June 12, 1915, p. 1023.

——— Thawing methods at Fairbanks. Eng. and Min. Jour., July 3, 1915, p. 1.

——— Stoping methods at Fairbanks. Eng. and Min. Jour., September 25, 1915, p. 503.

——— Sluicing methods at Fairbanks. Eng. and Min. Jour., December 18, 1915, p. 993.

——— Winter drift mining at Fairbanks. Eng. and Min. Jour., October 30, 1915, p. 707.

——— Handling gold dust at Fairbanks. Eng. and Min. Jour., November 7, 1914, p. 817.

——— Hydraulic mining at Circle. Eng. and Min. Jour., December 19, 1914, p. 1104; December 11, 1915, p. 962.

ELLSWORTH, C. E., AND DAVENPORT, R. W., Surface water supply of the Yukon-Tanana region, Alaska. U. S. Geol. Survey Water Supply Paper 342, 1915, 343 pp.

EVANS, G. H., Practical notes on hydraulic mining. 1897, 48 pp.

GARDNER, W. H., Gold dredging—actual recovery compared with estimates. Eng. and Min. Jour., September 11, 1920, p. 515.

GIBSON, A., Drift mining in frozen gravel at Cape Nome. Min. and Sci. Press, March 7, 1914, p. 405.

——— Third beach line at Nome. Min. and Sci. Press, April 15, 1914, p. 687.

——— Thawing frozen ground for placer mining; steam thawing. Min. and Sci. Press, January 17, 1914, p. 143.

HALEY, C. S., Elevating 10-cent gravel at a profit; rubble elevator operation. Min. and Sci. Press, April 13, 1912, p. 530.

——— Gold placers of California; mining methods. California State Min. Bur. Bull. 92, 1923, 167 pp.

HALL, H. H., Water supply for Klondike hydraulic mines. Min. and Sci. Press, August 28, 1915, pp. 321, 324.

HAZZARD, F. H., The saving of fine placer gold. Eng. and Min. Jour., August 26, 1911, pp. 394–396.

HAZZARD, F. H., AND PARKER, G. L., Surface water supply of Seward Peninsula, Alaska. U. S. Geol. Survey Water Supply Paper 314, 1913, pp. 51–249, 255–269.

HORNOR, R. R., Notes on black sand deposits of southern Oregon and northern California. Tech. Paper 196, Bureau of Mines, 1918, 42 pp.

HUBBARD, J. D., Drift mining in California. Eng. and Min. Jour., November 17, 1917, pp. 863–866.

HUTCHINS, J. P., Dredging in the Russian Empire. Eng. and Min. Jour., vol. 98, November 14, 1914, p. 857.

——— Drift gravel mining in eastern Siberia. Eng. and Min. Jour., May 11, 1920, p. 859.

——— Prospecting and mining gold placers in Alaska; Mineral resources of Alaska, 1907. U. S. Geol. Survey Bull. 345, 1908, pp. 56–68.

JANIN, CHARLES, Placer mining methods and operating costs. Bull. 121, Bureau of Mines, 1916, p. 42.

——— Gold dredging in the United States. Bull. 127, Bureau of Mines, 1918, 216 pp. (Treatise on the history, topography, and geology of dredging areas, prospecting, details of dredge construction, operation, costs, etc.)

——— Gold dredging in United States and Alaska. Min. and Sci. Press, January 10, 1914, p. 93.

——— Gold dredging on Seward Peninsula. Min. and Sci. Press, September 28, 1912, p. 394.

——— Recovery of gold in dredging. Min. and Sci. Press, November 7, 1914, p. 717.

——— Recent progress in the thawing of frozen gravel in placer mining. Tech. Paper 309, Bureau of Mines, 1922, 34 pp.

JANIN, CHARLES, AND WINSTON, W. B., Gold dredging in California. California State Min. Bur. Bull. 57, 1910, 300 pp.

JENNINGS, HENNEN, The history and development of gold dredging in Montana. Bull. 121, Bureau of Mines, 1916, 63 pp.

KATZ, F. J., Methods of placer mining in the Fairbanks district; Fairbanks quadrangle, Alaska. U. S. Geol. Survey Bull, 525, 1913, pp. 115–131.

KNOX, N. B., AND HALEY, CHARLES, Mining of alluvial deposits. Min. Mag., 3 parts, February, March, and April, 1915, 31 pp.

LONGRIDGE, C. C., Gold and tin dredging. 3d ed., Min. Jour. (London), 1915, 425 pp.

——— Hydraulic mining. Min. Jour. (London), 1910, 335 pp.

McCARTHY, E. E., Stripping frozen gravel in the Yukon. Min. Mag. (London), vol. 10, April, 1914, pp. 289–295.

MERRIMAN, M., Treatise of hydraulics. 1903, 565 pp.

MOLINE, A. H. P., Australian practice in pump dredging. Min. Mag., July, 1917, pp. 12–26.

NEW ZEALAND, MINISTER OF MINES, Mining handbook, 1906. Report of New Zealand Minister of Mines, 1902.

NICHOL, J. M., Metallurgy of alluvial mining. Min. and Sci. Press, May 29, 1915, pp. 837–840. (On black sand and fine gold.)

PAYNE, H. M., Siberian drift-mine timbering. Eng. and Min. Jour., June 9, 1917, p. 1019.

——— Development and problem of the Yukon. Trans. Canadian Min. Inst., vol. 16, 1913, p. 228.

——— Notes on Yukon mining problems. Trans. Canadian Min. Inst., March, 1917, pp. 188–206. (Steam thawing.)

PEELE, ROBERT, AND OTHERS, Mining engineers' handbook. New York, 1918, 2375 pp.

PERRET, LEON, Prospecting frozen ground in Siberia. Min. and Sci. Press, June 22, 1912, p. 856.

PERRY, O. B., Development of dredging in Yukon Territory. Eng. and Min. Jour., vol. 100, December 25, 1915, pp. 1039–1044. (Account of operation and steam thawing.)

POWER, H. T., Timbering in deep placer mining. Min. and Sci. Press, August 11, 1917, pp. 191–194.

PURINGTON, C. W., Methods and costs of gravel and placer mining in Alaska. U. S. Geol. Survey Bull. 263, 1905, 273 pp.

——— Hydraulic elevator work on Anvil Creek, Nome, Alaska. Min. and Sci. Press, April 26, 1913, p. 615.

——— Cleaning up at Nome hydraulic mine. Min. and Sci. Press, May 3, 1913, p. 653.

——— The Seward Peninsula exploration and mining of gravel deposits. Min. Mag., March, 1913, p. 203.

RADFORD, W. J., Methods of testing placer gravels. Min. and Sci. Press, July 4, 1914, p. 5.

——— Rocker for washing gravel. Min. and Sci. Press, June 8, 1912, p. 801.

RICKARD, T. A., Dredging on Seward Peninsula. Min. and Sci. Press, November 28, 1908, p. 734.

——— Dredging on the Yukon. Min. and Sci. Press, August 29, 1908, p. 290; September 12, 1908, p. 354. (Also steam-thawing methods.)

——— Mining methods in far North. Min. and Sci. Press, December 12, 1908, p. 810.

ROSE, T. K., The metallurgy of gold. London, 1898, 514 pp.

UNITED STATES GEOLOGICAL SURVEY, Bulletins, papers, and maps, various mining districts of Alaska.

VAN WAGENEN, T. F., Manual of hydraulic mining. 1913, 123 pp.

WILSON, E. B., Hydraulic and placer mining. 3d ed., 1918, 412 pp.

WIMMLER, N. L., Placer mining in Alaska in 1922, 1923, 1924. In Stewart, B. D., Annual report of mine inspector to Governor of Alaska, 1923, 1924, 1925.

YOUNG, G. J., Elements of mining. 1916, 628 pp.

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